Report No. CG-D-43-95

IMPROVING THE PERFORMANCE OF OIL SPILL CONTAINMENT BOOMS IN WAVES

Part I - Literature Review
Part II - Physical Model Study: Procedure and Results

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FINAL REPORT
September 1994

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National Technical Information Service, Springfield, Virginia 22161

Prepared for:

U.S. Coast Guard
Research and Development Center
1082 Shennecossett Road
Groton, Connecticut 06340-6096

and

19960220 101

U.S. Department of Transportation
United States Coast Guard
Office of Engineering, Logistics, and Development
Washington, DC 20593-0001

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Technical Report Documentation Page

1. Report No. CG-D-43-95	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle IMPROVING THE PERFORMANCE OF OIL SPILL CONTAINMENT BOOMS IN WAVES PART I - LITERATURE REVIEW, PART II - PHYSICAL MODEL STUDY: PROCEDURE AND RESULTS		5. Report Date September 1994
		6. Performing Organization Code
7. Author(s) Robert L. Van Dyck		8. Performing Organization Report No. R&DC 32/95
9. Performing Organization Name and Address Stevens Institute of Technology Davidson Laboratory 711 Hudson Street Hoboken, NJ 07030		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6090	Department of Transportation U.S. Coast Guard Office of Engineering, Logistics, and Development Washington, D.C. 20593-0001	13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code

15. Supplementary Notes
U.S. Coast Guard R&D Center contact: Kenneth Bitting, 203-441-2733.

16. Abstract

This study to improve boom performance is intended to complement the ongoing oil spill research at the Ohmsett facility and within the Marine Spill Response Corporation. After an extensive review of the literature, new model testing instruments and procedures have been developed to provide a direct measure of containment boom heave response to wave excitation at several points along a catenary-towed boom. Measurements have been made in reproducible regular, irregular and breaking waves for various generic model boom configurations over a range of wave characteristics and boom buoyancy/weight ratios at typical towing speeds. Total towing forces have also been measured and are scaled up to full size predicted drags.

Based on analyses of the results, highly flexible booms with buoyancy/weight ratio of at least 10 and sufficient freeboard are recommended for open sea operation with a catenary tow at about 0.5 knot.

17. Key Words	18. Distribution Statement
Oil Spill Containment Booms Booms Boom Conformance in Waves	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. SECURITY CLASSIF. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

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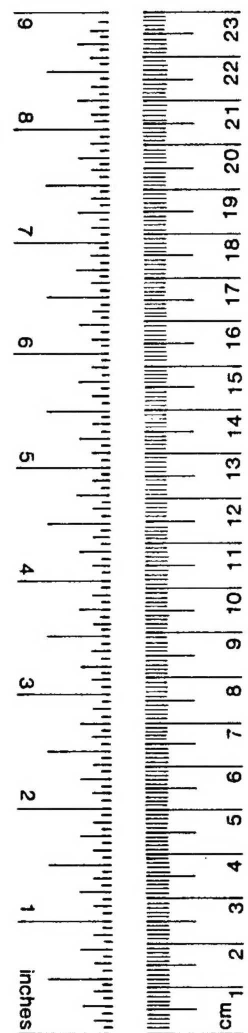
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

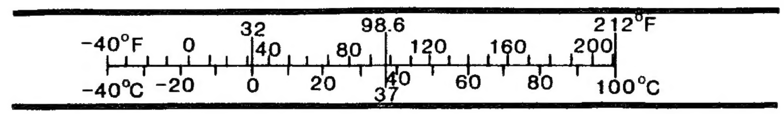
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



EXECUTIVE SUMMARY

A focused effort to improve boom performance in waves is underway at Stevens. This study is intended to complement the ongoing oil spill research at the OHMSETT facility and within the MSRC. After an extensive review of the literature, new model testing instruments and procedures have been developed to provide a direct measure of containment boom heave response to wave excitation at several points along the boom. Measurements have been made in reproducible regular, irregular and breaking waves for various generic model boom configurations over a range of wave characteristics and boom buoyancy-to-weight ratios at typical towing speeds or currents. A model scale of 1/8 allows for tests in regular waves up to 12 ft high full scale at 12:1 length/height ratio and irregular waves with significant heights of up to 8 ft full scale. Breaking waves can be generated at catenary boom models as they are towed down the tank. Total towing forces have also been measured and are scaled up to full size predicted drags.

The results of tests of three different size models, all scaled to the same 4 ft high prototype boom, show no scale effects on heave response to the various types of waves. A buoyancy/weight ratio of 10 or greater was found to improve heave conformance with the waves at optimum towing speeds of about 0.5 knot. Short wavelength waves, requiring the highest frequency response, are shown to be the most difficult conformance problem for oil containment booms. This is especially true because a catenary tow shape focuses waves near the vertex, thereby amplifying the wave height and the resulting motions near the center of the boom. For this reason, light weight, highly flexible booms with maximum buoyancy/weight ratio and sufficient freeboard are recommended for open sea operations. It is further recommended that model comparison tests be run at Stevens for optimization of configurational design variations in conjunction with full scale oil spill tests at the OHMSETT facility.

GLOSSARY

BARRIER/BOOM	any floating mechanical device intended to prevent the spread of floating oil, increase the thickness of floating oil, or divert the flow of floating oil.
BOOM HEIGHT	the total vertical height of the barrier at rest in calm water. The sum of draft and freeboard.
BOOM DRAFT	the maximum distance below the calm-water surface of any boom segment not part of the towing assembly or connector.
BOOM FREEBOARD	the vertical height of the barrier above the water line in calm water
BOOM SKIRT	the structural component of an oil spill boom that hangs beneath the flotation member. There is often a ballast chain or other weight at the bottom of the skirt to hold it vertically in the water.
CATENARY CONFIGURATION	the "U" or "J" plan view shape formed by a boom when towed by two vessels or held in place at two fixed mooring points.
HARBOR CHOP	an irregular condition of the water surface produced by an interference pattern of waves generated at the OHMSETT tank.
OHMSETT	"Oil and Hazardous Material Simulated Environmental Test Tank". The National Oil Spill Test Facility at NWS Earle, Waterfront Area, Leonardo, N.J.
SIGNIFICANT HEIGHT	the average of the one third highest wave height measured crest to trough; used to characterize the sea surface.
TEST TANK	a wave tank which can create a relative velocity between a boom and the water surface; a towing tank.
TOW SPEED	the relative speed difference between a boom and the water in which it is floating. Current is equivalent.
RANDOM SEA	irregular waves having a broad frequency spectrum; usually characterized by a significant height and period of maximum energy.
REGULAR WAVES	repetitive waves of the same amplitude and frequency (with a very narrow frequency band).

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INTRODUCTION TO PART I

As a result of several recent castastrophic oil spills, numerous public and private efforts have been initiated that seek to protect the marine environment from the accidental release of petroleum products. These have included the Oil Pollution Act mandating certain design and operational changes in the transport and handling of petroleum cargoes; the creation of the industry-sponsored Marine Spill Response Corporation; and the recent re-commissioning of the OHMSETT oil spill research facility. These initiatives are evidence, not only of the increased public concern about marine oil spills, but also of the inadequacies of the present state-of-the-art in our knowledge of spill behavior and cleanup/containment technology.

A continuing problem in oil spill mitigation efforts is the loss of effectiveness of spill containment booms in waves. Essentially, this problem is the result of the inability of the boom to conform to the water surface with sufficient freeboard and skirt depth to avoid the loss of oil. As a consequence, booms deployed in all but protected waterways have limited utility in stemming the spread of a surface spill. Since major accidental spills often occur in open waters exposed to heavy seas and swell, the loss of boom effectiveness severely hampers oil recovery efforts. Recent regulations requiring rapid response plans and on-board mitigation systems will, in such cases, lose much of their intended function.

Clearly there is a need for a focused effort to improve boom performance in waves. This study is intended to complement the ongoing oil spill research mentioned previously, particularly that being carried out at the OHMSETT facility and within the MSRC.

This first report is a review and discussion of previous research and design efforts at modeling and analysis of containment boom performance in waves. The currently available state-of-the-art booms will be described. Reduced effectiveness in the open sea will be studied with special emphasis on the perceived causes and potential solutions to this problem which becomes exceedingly crucial when large spills occur near a coastal environment.

PREVIOUS WORK

A search of the literature on containment boom performance, design variations and previous modeling efforts resulted in the References listed chronologically at the end of this report. Naturally many more volumes have been written on the subject in the last thirty years. The extensive references in each of the papers perused provides a more complete range of research done on the oil spill containment problem. In this report, we have tried to summarize the more directly pertinent references relating to the performance of containment booms in rough water. The listings here will be broken down into two major areas of interest: (1) ranges and types of boom designs available and (2) experimental procedures and analyses used to date.

CONTAINMENT BOOMS

This section will describe the general types and variations of boom designs available as shown in the "1993 World Catalog of Oil Spill Response Products"-Edited by Robert Schulze.[20] This very useful and comprehensive reference contains hundreds of booms listed according to Manufacturer/Distributor and broken down according to recommended use in (1) calm water - C, (2) protected water - P and (3) open water - O. There are 33 pages of open water boom listings alone with up to 3 design variations per page. Obviously, no single design can solve all oil containment emergencies. Boom terminology is explained in the GLOSSARY.

Open water has been defined by the new ASTM Standard F625 to correspond to the operating environment definitions listed in earlier editions of the Catalog [20] as "Offshore", where significant wave height is less than 6 feet (or 2 meters). Also, it is suggested in a draft ASTM Standard presented as Table 1.3 in the catalog that minimum reserve buoyancy to weight ratio of 9:1 be used for Open Water Boom selection, but that this figure will be increased in future revisions of the Standard. Overall boom heights range from 36 to 90+ inches for Open Water in this same Table.

Another textbook on the subject, "The Control of Oil Pollution"-Edited by J. Wardley-Smith in 1976,[5] also describes boom types, uses and operational characteristics.

Three basic types of booms have proven successful in containing oil and floating oil-like materials. These types, listed in order of most used, are: (1) curtain booms, (2) fence booms and (3) external tension booms (unidirectional operation only); see Figure 1A. Each type has its place depending on the quantity and location of a spill.

Chapter 1 of the World Catalog[20] is recommended reading because of its excellent forty page discussion and description of containment boom design, performance and selection requirements. A brief summary of the comments directly related to open sea operations and wave limitations of available boom designs can be given here to complete the picture. Figure 2A depicts four of the principal failure modes of containment booms.

Two criteria mentioned for improving short period wave operations are: (1) flexibility with floating sections no longer than 3 to 4 feet, or continuously flexible flotation chambers and (2) a high value of reserve buoyancy to weight ratio to ensure heave stiffness in order to follow larger waves. One additional requirement for good wave following and operation in high currents is high roll stiffness, where roll is the relative angular attitude of the boom cross section. Either heavy ballast weights at the bottom of the skirt or flotation volume well outboard of the boom section centerline are used to provide large roll restoring moments to maintain a near vertical boom attitude along its length.

Naturally, adequate freeboard and skirt draft must be provided in order to operate successfully in the open sea. Surprisingly, with the normal catenary deployment in waves a 12 inch skirt draft performs as well as or better than a 24 inch skirt.[14] A maximum 18 inch skirt draft limit is sometimes mentioned for operation in fast currents. Also, freeboard height should only be large enough to prevent splashover without allowing excess rolling moments to develop due to high wind forces acting on the exposed upper surface of the boom.

EXPERIMENTAL AND ANALYTICAL STUDIES

Although spill containment booms have been around a long time and earlier analytical studies exist, two papers from a Joint Conference on Prevention and Control of Oil Spills given by API and FWPCA in December

1969[1,2] are of particular interest. The first paper by Commander Lehr of the U.S. Coast Guard and J.O. Scherer, Jr. of Hydronautics describes predictions of boom loads, shapes and motions.[1] Some model tests were undertaken to verify the analytical study using a simplified segmented model. The results are incomplete at the time of the paper. However an important design goal relating to seakeeping capability of oil spill cleanup systems is stated. That is, to "perform efficiently in 40 mph winds, 2 knot currents and 10-foot significant height waves." This recommendation by the authors also is extended to "survive, though not performing effectively, in 60 mph winds, 2 knot currents and 20 foot significant height waves." These goals are still valid for today. Larger than 10 ft significant height waves tend to mix the oil with the water and make containment and pickup very difficult.[3]

The second paper by Dr. Wicks of Shell Oil[2] presents "experimental results and their interpretation on the effects of water currents on oil containment with booms." He discusses and illustrates the important physical phenomena controlling the flow conditions that lead to failure of a barrier. His experimental work used a 60 ft long circulating water channel 6 feet tall by 6 feet wide and a plywood board to represent a section of "skirt." Showers of oil droplets were observed to be torn off from a head wave formed at the bottom of the oil above about 0.6 fps. If the slick was long enough the oil torn off could be recovered before passing under the skirt. Otherwise, containment is lost. Dr. Wicks computes the trajectories for oil of different specific gravities and surface tension values.

Milgram and O'Dea in 1974 evaluate the strength and seakeeping ability of arbitrary barriers using both model tests in a swimming pool and theoretical and semi-empirical analyses. The effects and various methods of carrying the tension throughout the barrier are studied. Model scaling is discussed and it is concluded that fabric thickness, strength and bending stiffness cannot be scaled for a small scale model due to difficulty in obtaining such weak fabric. It is stated that the folding tendency of the fabric cannot be determined from model tests but that all other aspects of barrier motion can be determined.[4] "Model tests can be used to estimate the heave, sway and roll motions of a barrier."

Milgram in a 1977 paper[6] shows photographs of the build up of the head wave on the bottom of oil on water at a barrier and failure due to separation above a one knot current. A later paper[7] shows an interesting combination barrier and weir-type skimmer oil recovery system that was first tested in the OHMSETT facility in 1975 and then demonstrated in sea trials with the U.S. Coast Guard in May 1976. Weir skimmers are inherently simple but good oil collection requires that the attached boom follow the vertical motion of the waves. The Coast Guard barrier design was used and performed well in seas up to 5 ft significant height.

McCracken[8] describes the OHMSETT standardized test procedures and results for eight boom systems. Booms were first tested for stability capabilities over a wide range of wave conditions without oil and then in wave conditions within their operational stability limits with two types of oil. In another paper[9] recovery efficiency was measured for simulated hazardous floating materials and compared with previous oil recovery tests. No differences were shown.

Milgram and Van Houten[10,11] describe the mechanics of a restrained layer of floating oil analytically and using the flume at MIT. The second paper studies the oil-water interface stability with respect to movement of the oil slick by the water waves.

Corpuz and Griffiths[12] performed open sea field tests for the Coast Guard of six offshore oil containment booms in 1977 in the Gulf of Mexico but without oil. One of the major U.S. made products performed well in significant wave heights of 8 to 10 feet and survived in waves up to 14 feet. Signs of possible containment failure due to splashover were observed only occasionally. Results indicated that "both ballast and reserve buoyancy of offshore booms should be as high as practical."

Environment Canada in 1980[13] tested six offshore booms in severe seas with small amounts of oil. The results indicated some oil could be recovered if the pick up had been attempted within 45 minutes for the best performing product.

Smith and Lichte[14] present a summary of the U.S. EPA's OHMSETT testing from 1974 to 1979. Descriptions of the facility, its capabilities and wave

making system are given. Test procedures depend on product being tested.

A National Marine Pollution Program Plan for research, development and monitoring for 1981-1985[15] stated that federal program emphasis has shifted to the containment and pick-up of floating hazardous materials requiring more study of the necessary technology.

Environment Canada's winter evaluation of skimmers and booms[16] describes good agreement with theoretical curves of boom towing force as a function of gap ratio at smaller gap ratios but at larger gap ratios the measured forces are lower. In the offshore tests of the Vikoma Seapack it was noted that the upper and lower cylinders of the boom set up local currents as the boom moved up and down in waves. This kept oil away from the boom surfaces.

Borst and Lichte[17] in 1983 and 1984 performed two series of tests on five booms. One series was in the OHMSETT facility and the second series of open-water tests was in the Raritan Bay. A standardized test matrix was used for oil-holding ability. Wave conformance and endurance were observed in the tank under controlled conditions. Wave conformance of 500-ft booms deployed in the bay was then compared with the 100-ft lengths used in the tank, but lack of conformance was more obvious in the bay tests. Additional tests were planned in an effort to obtain better correlation, but the results are unpublished.

Meikle[18] in 1987 explains Environment Canada's more recent work in marine-spill countermeasures. He mentions the Vikoma booms in inventory as being at least as good as some of the newer booms tested.

Finally, a Test Protocol for the Evaluation of Oil-Spill Containment Booms[19] has been updated to the present and serves as a guide for current OHMSETT and offshore testing. This reference, together with the contents of the 1993 World Catalog,[20] will be used for selecting generalized boom shapes and proportions relative to the test tank at Stevens for the next phase of this study.

GENERAL RECOMMENDATIONS

Based on previous experience and analyses the following recommendations

are made concerning oil boom design and selection for extending open sea operations from waves of 6 ft significant height to as much as 10 ft:

(1) good flexibility with floating sections no longer than 3 to 4 feet, or continuously flexible flotation with a smooth surface.

(2) reserve buoyancy/weight greater than or equal 9:1.

(3) high roll stiffness with either heavy ballast weights at the bottom of the skirt or flotation volume arranged to provide large roll restoring moments.

(4) total height large enough to provide freeboard above maximum wave splashover and skirt or fence draft sufficient to contain the oil and prevent drainage failure at the expected towing or drift speeds.

(5)sufficient strength to survive extreme seas and to take the towing forces in winds of 40 mph at 2 knots towing speed in 10 ft significant height waves.

There are booms built today that can possibly accomplish the desired objective of containment in 10 ft waves. However, open sea tests are few and difficult and accurate measurements, even of the sea conditions, are usually limited.

A test plan will be developed for a model examination of boom response to large waves using the Stevens tank. This will require a basic scale ratio of 1/4. Boom gap will be restricted to about 8 ft for the model, thereby allowing a 12 ft model boom length to fit the prescribed test gap ratio of 2/3 and a 24 ft boom length to fit a gap ratio of 1/3. A model boom draft of one foot or less will be required due to the tank depth of 5 feet for large waves. Waves up to 18 inches high can be made with this depth, representing 6 feet for a 1/4-scale and 12 feet for a 1/8-scale model, also to be included in the study.

INTRODUCTION TO PART II

This is the second part of a study concerned with improving the performance of oil spill containment booms in waves. Uniform tank testing procedures are developed for assessing boom performance in waves based on a previous review and adopted good practice. Guidelines are provided for test setup and a wave/current test matrix is developed that allows for the subsequent boom analyses and comparisons. In addition, data analysis procedures are explored for predicting each boom's response to full scale random sea waves.

A series of generic model booms was developed, constructed and tested. A brief analysis was made to compare the effects of variations in scale, buoyancy/weight ratio, speed, wave height and gap/length ratio on heave response to waves and total towing force. All final tests were performed in the No. 3 towing tank at the Davidson Laboratory of Stevens Institute of Technology during April 1994. Many of the tests were witnessed by Lt Michael J. Roer of the U.S. Coast Guard as well as other interested parties.

The objective of this study is to produce a document of model testing procedures and analysis techniques that will assist future efforts in containment boom research and development for extending open sea operations.

MODELS

In accord with the findings of Part I of this study the most flexible, smooth-sided longitudinal shape possible was selected as the basic boom model to be tested in the catenary tow condition; see Figures 1-8. Two primary variables that had to be examined were model size (to best fit the tank cross section) and non-dimensional buoyancy/weight ratio. Table 1 lists the dimensions, materials and resulting B/W ratios available as a result. The latest ASTM recommended B/W value of 10 was included for all models. In addition, boom gap/length ratio could be varied by length changes with the 8 ft gap width dictated by tank width. Wave size limits available in the towing tank then determined the boom scale factors to be considered, since boom height for open sea operations is indeterminate at present. However, it would appear to be at least 4 ft based on current

practice.[16] Some have recommended a boom height at least equal to operational wave height for a barrier that contains the boom tension members internally.[13] The resulting air-inflated curtain boom cross section was developed and three size variations were constructed by Slickbar Products Corporation to dimensions specified by the Davidson Laboratory. Three scales were decided upon for a 4 ft high full scale boom -- 1/8, 1/4 and 3/8 -- with a basic length of 24 ft with additional changes in this length possible for future testing of gap/length ratio. These extremely light weight boom models permitted the inclusion of more variation in B/W ratio than had originally been planned. The variations in B/W were obtained by adding lead weights to the two larger booms in increments of 0.465 lb and by different sash chains threaded through the bottom fold of the smallest 6 inch height boom; see Table 1 and Figures 3, 4 and 5. A special bleed fitting was made and used to measure and set the very low air pressure of 0.5 inches of water over atmospheric in the buoyancy chambers. An available Pennwalt Corp. Electro-Pneumatic Calibrator Series 65-125, by Wallace and Tiernan Div. shown in the middle of Figure 7 was used to read the pressure which remained very constant in the tow tank.

TEST CONDITIONS

Previous research with catenary towed booms and oil has shown an optimum tow speed of from 0.5 to 0.7 knot with a critical speed of about 1.0 knot above which oil starts to pass under the boom at a rapid rate. For this reason a model test speed range equivalent to currents or relative tow speeds of from 0 to 3 knots full scale was selected. Preliminary trial runs in calm water soon eliminated the 3 knot equivalent test speed and resulted in an upper practical tow speed limit of 2 knots. Table 2 lists the final ranges of all variables tested. The upper limits of the computer controlled wavemaker allow up to 18 inch or 1.5 ft regular waves at a minimum length/height ratio of 12:1 to prevent breaking. Thus, 0.5, 1.0 and 1.5 ft regular 12:1 waves were included.

A maximum irregular ITTC wave with a Pierson-Moskowitz spectral distribution of heights can be generated with up to 1.0 ft significant height waves and the corresponding period of maximum energy of 2.768

seconds. Similarly, a 0.5 ft significant height of 1.957 sec maximum energy period and a 0.75 ft significant height irregular wave of 2.397 sec period were included in the wave/current test matrix. Note that early problems with the computer controlling the wavemaker cut short and even prevented some runs in the 1.0 ft significant height waves for the 1.0 ft height boom. This was later rectified and this largest irregular wave was included for all other models tested. A third type of wave available for these tests was included in order to complete the picture for the video observations. Namely, breaking waves to show the behavior of containment booms under the severest wave (and weather) conditions.

Appendix A shows the measured model wave spectra for the three irregular wave sizes tested as well as an oscillograph time history of the breaking wave developed from deep-water breaking wave theory. This breaking wave is made through a sequence of seven waves which produce one breaking wave of large magnitude in a repeatable manner down the length of the towing tank.

APPARATUS AND PROCEDURE

Figures 1 and 2 show sketches of the model and support apparatus towing arrangement. Figure 6 shows photographic close-ups of the 150 lb stainless steel drag balance, cross-tank beam of adjustable span and height with tow struts system (one strut shown), one heave transducer and, finally, the four 4 ft tall wave struts mounted at fore and aft locations corresponding to the heave transducer locations along the boom. Figure 1 shows how the aft 3 wave struts were relocated for each different boom length corresponding to the wave phasing at each heave unit location. Special rigid support tracks were constructed and mounted parallel to the model centerline 2, 3 and 4 ft outboard and approximately 3 ft above mean water level. The four specially designed heave transducers were built in house after early trial runs revealed the need for them. Their specifications as finally constructed include: 16 gram low inertia pulleys, 60 + inches of heave travel with constant 0.1 lb lift force and ±0.01 lb total friction (even with misalignments of up to 6 inches at the water surface) using a linear output Bourns Series 3540 10-turn pot. Special new bridge circuits were built for the four wave wires to provide extremely good linearity and response to wave

elevation with better stability independent of small electrical currents in the tank.

Swivel-mounted tow yokes were attached to each boom end and were clipped to heavy duty fishing swivels at the bottom of each towing strut at the mean water level. A five foot yoke length was used for 24 ft boom length tests while a four foot yoke length was required for the 12 ft boom length in order to keep the tow strut spacing within the tank width for the 8 ft gap at the forward ends of the boom catenary; see Figure 1. A light weight Nylon return string was attached to each boom at the vertex. This string was long enough to remain slack throughout the largest heave excursions and only become taut when returning the model to the wave beach end of the tank to prepare for a new run. This string also protected the low force heave transducers from running all the way out to their stops during reverse runs.

Each test run was made by starting the waves, then starting the tow carriage (except for zero speed runs) when the waves reached the beach and filled the tank. Video recorders, and oscillograph recorders were started just prior to each run. The computer was made ready to read data on all channels once the model was up to steady speed where a pulse signals it to start and stop taking data. The video records show each model from the beginning to the end of a run.

The length of the bottom tension cable of each new boom had to be adjusted or "tuned" to provide the optimum towing attitude in calm water trials prior to running in waves. Mr. Edward Tedeschi of Slickbar Products Corporation, an experienced boom engineer, guided the test crew in this important procedure.

DATA PROCESSING

Each channel of instrumentation was linear and was calibrated prior to testing. Reference zeros were taken before each group of runs. Oscillograph records were taken for all runs in order to monitor the behavior of each channel transmitted to the Masscomp computer. Data were sampled 20 times a second and were processed on the in-house computer for mean values, rms (root-mean-square) values and maxima (peaks) and minima (troughs) where applicable during rough water testing throughout the 70 ft

data trap with the model at constant speed. At zero speed, data was taken for 128 seconds with the model oscillating in the wave train. During irregular and breaking wave tests a peak-trough analysis was carried out on all heave and wave channels to compute the mean, rms, the number of oscillations, the average of the peaks and troughs, the average of the 1/3-highest and the 1/10-highest peaks and troughs and the extreme values of each. These were output in the results Table 6 in a two-line format: mean/rms, oscillation/buffer and peak/trough. In this statistical analysis spurious oscillations are suppressed by means of "buffers", which are minimum amplitude limits set to eliminate electrical or vibrational noise on a data channel. Thus, oscillations smaller than the buffer riding on the back of larger waves in the individual time histories are neglected.

PRECISION

The precision of the measurements made during these tests is estimated to be within the following ranges model scale:

Measurement	Precision	Range
heave	±0.30 in	60 in
wave (elevation)	±0.10 in	40 in
drag	±0.30 lb	200 lb
speed	±0.01 fps	100 fps
period regular waves	±0.002 sec	
period of max. energy irregular waves	±0.01 sec	
period breaking waves	±0.05 sec	

RESULTS

The results of these tests are presented in several tables in various formats. Table 3 is a complete log of the video runs and is to be used when viewing any of the 4 tapes that include about 6 hours and 45 minutes of low speed running. Tables 4, 5 and 6 give all the data model scale. Tables 7,

8 and the data comparisons in Table 9 are given for a full scale 4 ft high boom using Froude scaling laws and the scale ratios selected for the three different height models. Full scale drags include a correction for the density of sea water at 59 deg F as compared with fresh water at 70 deg F in the towing tank. Table 9 presents the influence of variations in scale, B/W, wave height, gap/length ratio and tow speed on vertex heave response and drag.

Figures 9 through 17 show direct comparisons of superimposed heave and wave time histories of the model responses at the four locations along each boom in 0.75 ft significant height irregular waves for twenty second samples of the runs.

Figures 18 through 20 present model response amplitude operators (RAO) computed from the digitized time history measurements in 0.5 ft significant height irregular waves at the three different buoyancy/weight ratios covered for the 1 ft x 24 ft model boom. Figures 21 through 23 show the same three irregular wave RAO examples but with superimposed RMS heave response ratios measured in regular waves at specific frequencies of encounter.

Figure 24 shows predicted full scale drag as a function of speed for the several model scales and for three values of B/W for the intermediate (1/4) scale model.

The heave data and responses for the 1 x 12 ft model boom at locations 2 and 3 were eliminated from the results tables because of serious misalignments made in mounting the connections to this short length boom model. Since this did not affect the response of the boom at the most important locations 0 and 4, the tests were not repeated.

ANALYSIS AND DISCUSSION

A first analysis begins with the model scale results presented in Tables 4, 5 and 6 with test speeds listed by run number in Table 5 as well as encounter frequency (2Π/Te) for all regular wave runs. Table 5 RMS heave response ratios are presented for all runs but are particularly meaningful for regular wave runs with specific wave encounter frequencies. It was first believed that the magnitudes of these response ratios would be a key measure of boom conformance to a wave system. However, other factors enter in. For example, in short length waves a focusing or amplifying effect

develops due to waves either reflecting and/or being refracted off the inner boom surfaces. As a result, in short period and length waves - namely the 0.5 ft high by 6 ft long waves - the waves encountered at the centerline or vertex of the catenary tow shape are visibly greater in height than the waves measured outside of the boom nearer the wall; see Figure 1. In addition, the waves inside the boom can become irregular in a non-periodic manner. Thus, a flexible curtain boom cross sectional shape appears to reflect or focus short period waves at some tow speeds resulting in a heave response factor of much more than 1.0, up to 1.4, relative to the wave height measured at an outer location at the same longitudinal position along the boom. Since the primary area of interest is near the vertex when collecting oil, this makes analysis using this rms/rms factor or response amplitude much more difficult to interpret. These larger response amplitudes occur at the centerline (0) heave location for all boom combinations tested, indicating some reflection or focusing of all wave sizes and lengths. The other locations 2, 3 and 4 ft outboard of the centerline show responses much closer to 1.0, or less when poorer conformance is exhibited; see Table 5. More discussion of this will follow.

The second stage of analysis is to look more deeply into the irregular wave results whose statistics were measured and listed in Table 6. Time histories were plotted for 20 second samples of the runs for three boom sizes at three B/W ratios in 0.75 ft significant height waves for the model test speed corresponding to 0.5 knot full scale; see Figures 9 through 17. These directly superimposed comparisons of heave and wave measurements at the same locations 0, 2, 3 and 4 ft outboard of the centerline show how well these flexible curtain booms really do conform to the waves at appropriate tow speeds. The phasing correlation is very good in this rather large wave system and was observed to be similar in all size irregular waves.

The next step was to compute response amplitude operators for selected runs, see Figures 18 through 20, for three B/W ratios. These three figures show some differences in response to a given size irregular wave over the wide variation in B/W ratio. Further analysis was completed by plotting the regular wave response amplitudes at the specific values of frequency of encounter taken from Table 5 on these same irregular wave RAO plots, now called Figures 21 through 24, for locations 0, 2, 3 and 4 ft out. Study of Figures 21 - 24 shows remarkably similar trends in heave response variation

with encounter frequency over the band of regular wave frequencies tested. This finding is important because it shows that the results of regular wave testing over a range of frequencies are roughly equivalent to irregular sea heave response behavior. Regular wave test procedure is followed at OHMSETT for boom tests with oil in all but "harbor chop" waves.

Note that while RAO is non-dimensional in Figures 18-23 and would not change with scale factor, $2\Pi/Te$ is dimensional and would vary with scale factor. In fact, the frequency values would be reduced by a factor of $1/\sqrt{scale}$. Thus, $(2\Pi/Te)_{FS} = (2\Pi/Te)_{MS} \times 1/\sqrt{scale}$, or wave encounters occur at a slower rate for a full scale boom. Maximum heave response is seen to occur at about 6 radians/sec for the 1/4 scale 1 x 24 ft boom model centerline location. This would become 3 radians/sec for an equivalent full size 4 ft high boom at 0.5 knot for all three B/W ratios. For future work, repeat runs at any given irregular wave height/speed condition would improve the correlation coefficient over a wider range of encounter frequencies for the RAO computer fit of resulting data. This would allow greater confidence in providing the variations in heave response for a given condition, since different height irregular waves would be expected to shift the encounter frequency and magnitude of heave response because of the basic non-linearity of the boom/wave system.

Figure 24 presents full scale drag variation as a function of speed for the wide range of boom lengths and B/W tested. As would be expected, lower B/W requires higher towing forces. These forces also vary with boom length and wave height to varying degrees as has been described before.[20]

Table 9 has been prepared in order to compare the effects of the most important parametric variations on centerline heave response and required towing force. For these comparisons all speeds and drag forces have been expanded to full scale values using the listed model scale ratios, resulting in a 4 ft boom height for each size model with the given dimensions. The first comparison shows a mean value of centerline heave response of 1.4 ±.13 for all three model scale ratios for both 0.5 and 1.0 knot tow speeds in 12:1 regular waves at B/W = 10. The second comparison shows similar heave response values for B/W = 34 and 10 but a higher value for B/W = 4.4 of about 1.74 ±.09 for the 1/4 scale model results at both speeds. The third comparison of wave height effects on heave response shows slowly declining

response values as wave height increases - from 1.4 to 1.3 to 1.2 as wave height is increased from 4 to 8 to 12 ft at B/W = 10 and 0.5 and 1.0 knot tow speeds. Finally, the fourth comparison made is for the effect of gap/length ratio where doubling the ratio produces no statistically significant difference in centerline heave response to 4 ft high waves at 0.5 and 1.0 knot tow speeds.

Many other comparisons may be made using this data but these are the important variables and parameters. It was fortunate that the wave/speed test matrix focused on the shortest wave length regular waves because these 12:1 length/height waves with an approximately 1 second period model scale provided the most interesting behavior and measurements for these boom models. Video observations of all runs in these short length regular waves show the irregularities of wave motions and resulting heave motions developed particularly at the vertex location 0 of each boom. Study of the videos here shows that water splashes up at the vertex, where oil would be collecting and splashes back and over the boom occasionally as tow speed reaches 1.0 knot or higher equivalent full scale speeds. This same behavior is observed in all the short wave length regular wave runs.

As expected and demonstrated here, breaking waves will top any boom whose freeboard is less than the breaking height of the wave.

CONCLUSIONS

Scale model oil containment booms have been successfully designed, constructed and tested in waves at three different scale ratios. The measured heave responses to equivalent wave sizes show excellent agreement at useful towing speeds equivalent to 0.5 and 1.0 knot full scale for all three model scales at the boom vertex during catenary towing. Total required towing forces are different due to the different full scale lengths of boom dictated by the test tank width and, therefore, model gap available.

Three different buoyancy/weight (B/W) ratios were tested for each boom scale by varying skirt weights on these curtain boom shapes. The effects as shown and discussed reveal relatively small differences between B/W of 34 and 10 but somewhat poorer heave conformance with waves at B/W = 5. Towing drag forces naturally increase with lower B/W, since the booms sit deeper in the water as B/W is reduced.

Wave height is not the limiting factor for good boom conformance but rather wave steepness seems to be the dominant parameter, particularly at short wave lengths, where it becomes more difficult for the boom to respond fast enough to the rapid vertical motions of the waves. This explains why lower values of B/W exhibit poorer response than higher values because of the increased inertia that must be overcome. Apparently, B/W = 10 and above meets this critical need better than lower values.

Drag and boom tension forces increase rapidly with towing speed and (at a lower rate) for increasing boom length for the same gap/length ratio. Increasing gap/length ratio from 1/3 to 2/3 for the same full scale gap has relatively insignificant effect on vertex heave response but does increase drag forces at the same B/W and speeds of 0.5 to 1.0 knot.

RECOMMENDATIONS

The newly-designed apparatus, procedures and wave/speed test matrix developed for these tests demonstrates a method for obtaining and analyzing behavior of oil containment booms in all types of large wave systems. Comparisons between many different designs are now possible for optimization at reasonable cost prior to the need for actual full scale tests with oil. The calming effects of oil on water are not reproduced here in the small test tank but should be investigated at the larger OHMSETT facility designed specifically for testing oil spills. There, the optimum boom designs may then be studied more closely for oil control.

It is recommended for future tests that the middle size model boom height of one foot be used since it is the smallest at which a full range of B/W ratios are available due to strength and weight limits of available fabrics.

The computed curves of heave RAO as a function of frequency can be improved upon in future tests by making repeat runs at speed in various irregular wave events in order to increase correlation or predictability over a desired range of frequencies.

As demonstrated here, optimum towing speed is about 0.5 knot, or certainly less than 1 knot, where splash up at the vertex begins to be carried back over the boom. Buoyancy/weight ratio should be at least 10 or greater for best conformance with short wavelengths. Higher B/W values also

allow lower catenary towing forces.

Model data from these tests can be expanded to other larger scale booms and waves as long as the drag and speeds are scaled up also. For example, doubling the current model scales to 1/16, 1/8 and 3/16 (instead of 1/8, 1/4 and 3/8) would result in forces approximately 8 times those reported here but at corresponding full scale speeds of 0, 0.7, 1.4 and 2.8 knots for an 8 ft high full scale boom. The wave sizes would be doubled as well.

ACKNOWLEDGEMENTS

This project has been a product of the interest of many working toward one goal of improving oil spill containment boom operations in open sea waves. Starting with early recognition of the need for this work by Dr. Michael Bruno of Davidson Laboratory and his confidence that we could develop the necessary instruments and means for making accurate measurements using scale-model booms, to the production of new apparatus and test procedures, has involved many of the towing tank personnel. Particular thanks are to be given to the creation of the new wave bridges and heave transducers by Bob Weiss, Jan Nazalewicz and Doug Meding of our instrument and machine shop groups. The special carriage and model mounts by Charles Heyer contributed to a successful setup in the tank.

Prior to the start of this study much background help was supplied by Mr. James H. Nash of OHMSETT and Chapman Incorporated. In addition, Dr. J. H. Milgram of MIT was very helpful with a background discussion and supply of some of his references for the first part of the study. At this point, Mr. Ed Tedeschi of Slickbar Products Corporation was contacted and volunteered to build the model booms with the only stipulation that we keep him advised of the results as soon as they are available and include additional variations in buoyancy/weight ratio. As a result, our model booms were constructed to the highest standards of full-scale boom production but were scaled down using the lightest weight, rugged boom materials available to the dimensional specifications desired. Mr. Tedeschi's personal experience and hands-on help during the tests was greatly appreciated.

Special thanks are to be given to Lt Michael J. Roer of the U.S.Coast Guard for his patience and understanding during the trial phase of testing

in early April.

The interest shown and time spent by Mr. Kenneth R. Bitting of the U.S. Coast Guard Research and Development Center and Mr. James L. Simmons of MSRC during the planning and test stages of the study were very encouraging to the author.

Finally, our ocean engineering doctoral students who helped conduct the tests and prepare some of the report figures, Raju Datla and Ivica Grgas, are thanked for their help.

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TABLE 1

MODEL CONFIGURATIONS

Test Order	Boom Dimensions: Height	Boom Dimensions: Length	Boom Dimensions: Diameter	Boom Dimensions: Skirt Depth	Materials: Fabric	Materials: Density	Materials: Color	B Buoyancy	W Weight	B/W	Figures
	ft	ft	in	in		oz/sq yd		lb	lb		
4 6 5	0.5	24	2	3.5	Urethane coated Nylon	6.5	yellow	32	1.97 2.56 3.35	16.2 12.5 9.6	1,3
1 2 3	1.0	24	4	7.5	"	6.5	yellow	125	3.64 12.01 28.75	34.3 10.4 4.4	1,2,4
10	1.0	12	4	7.5	"	6.5	yellow	62.5	6.30	9.9	1,4
7 8 9	1.5	24	6	11.5	"	11.3	black	275	8.19 26.79 54.69	33.6 10.3 5.0	1,5

TABLE 2

MODEL TEST CONDITIONS

Test Order	Boom Configuration Height ft	Length ft	Gap / Length	B/W	Wave Configuration Type	Height ft	Length ft	Period Max Energy sec	Nominal Scale	Full Scale Speed knots
4	0.5	24	1/3	16.2	Regular	0.5	6	1.083	1/8	0,0.5,1,2
						1.0	12	1.539		0.5,1
						1.5	18	1.932		0.5,1
					Irregular	0.5	---	1.957		0.5,1
						0.75	---	2.397		0.5,1
						1.0	---	2.768		0.5
					Breaking	1.4	---	1.5		0.5,1
6	0.5	24	1/3	12.5		Repeat			1/8	Repeat
5	0.5	24	1/3	9.6		Repeat			1/8	Repeat
1	1.0	24	1/3	34.3		Repeat*			1/4	Repeat*
2	1.0	24	1/3	10.4		Repeat**			1/4	Repeat**
3	1.0	24	1/3	4.4		Repeat**			1/4	Repeat**
10	1.0	12	2/3	9.9		Repeat			1/4	Repeat
7	1.5	24	1/3	33.6		Repeat			3/8	Repeat
8	1.5	24	1/3	10.3		Repeat			3/8	Repeat
9	1.5	24	1/3	5.0		Repeat			3/8	Repeat

* 1 ft significant height irregular wave data limited
** No 1 ft significant height irregular wave data

Note - 3 knot (full scale) tow speed eliminated after trial runs

TABLE 3.1

VIDEO LOG

INDEX	RUNS	MODEL BOOM			WAVES			COMMENTS
		Height	Length	B/W	Type	Sig Ht	Period Max Energy	
hr:min:sec		ft	ft			ft	sec	
TAPE 1								
0:19	1-4	1	24	34.3	Regular	0.5	1.083	
9:03	5-7				Regular	1.0	1.539	
16:18	8,9				Regular	1.5	1.932	
22:12	10,11				Irregular	0.5	1.957	
17:54	12				Irregular	1.0	2.768	Short run, then wave machine failure
29:53	13,14				Irregular	0.75	2.397	
35:13	15,16				Breaking	1.4	1.5	
39:53	17-20	1	24	10.4	Regular	0.5	1.083	
47:50	21,22				Regular	1.0	1.539	
53:16	23-26				Regular	1.5	1.932	Runs 23 & 24,string short
1:03:33	27,28				Irregular	0.5	1.957	
1:08:35	29,30				Irregular	0.75	2.397	
1:13:49	31,32				Breaking	1.4	1.5	
1:17:37	33-36	1	24	4.4	Regular	0.5	1.083	
1:26:31	37,38				Regular	1.0	1.539	
1:31:51	39,40				Regular	1.5	1.932	
1:36:48	41,42				Irregular	0.5	1.957	
1:43:20	43,44				Irregular	0.75	2.397	
1:47:13	45,46				Breaking	1.4	1.5	Port air pressure low at end of Run 46
1:52:46	47-49	0.5	24	16.2	Calm	----	------	Air pressure set 0.6 inch of water
TAPE 2								
0:32	50-53				Regular	0.5	1.083	
10:55	54,55				Regular	1.0	1.539	
17:58	56,57				Regular	1.5	1.932	
25:07	58,59				Irregular	0.5	1.957	
32:52	60				Irregular	1.0	2.768	Says 6 in x 1.96 sec wave
37:33	61,64				Irregular	0.75	2.397	
44:32	63,64				Breaking	1.4	1.5	

TABLE 3.2

VIDEO LOG

INDEX	RUNS	MODEL BOOM			WAVES			COMMENTS
		Height	Length	B/W	Type	Sig Ht	Period Max Energy	
hr:min:sec		ft	ft			ft	sec	
TAPE 2 Continued								
51:57	65-68	0.5	24	9.6	Regular	0.5	1.083	Air pressure set 2.9 inches, Run 67 cut short
1:00:34	69,70				Regular	1.0	1.539	
1:07:33	71,72				Regular	1.5	1.932	
1:14:24	73,74				Irregular	0.5	1.957	
1:21:27	75,76				Irregular	0.75	2.397	
1:28:37	77				Irregular	1.0	2.768	
1:33:30	78,79				Breaking	1.4	1.5	
1:40:20	80-83	0.5	24	12.5	Regular	0.5	1.083	
1:50:11	84,85				Regular	1.0	1.539	
TAPE 3								
0:27	86,87				Regular	1.5	1.932	
7:36	88,89				Irregular	0.5	1.957	
14:39	90,91				Irregular	0.75	2.397	
21:59	92				Irregular	1.0	2.768	
26:39	93,94				Breaking	1.4	1.5	Run 93 end cut short
33:22	95-98	1.5	24	33.6	Calm	----	-----	Run 98 says 97
37:37	99-102				Regular	0.5	1.083	
44:26	103-105				Regular	1.0	1.539	
49:03	106,107				Regular	1.5	1.932	
53:02	108,109				Irregular	0.5	1.957	
57:02	110,111				Irregular	0.75	2.397	
1:01:21	112				Irregular	1.0	2.768	
1:04:14	113-115				Breaking	1.4	1.5	Run 114 repeat for waves

TABLE 3.3

VIDEO LOG

INDEX	RUNS	MODEL BOOM			WAVES			COMMENTS
		Height	Length	B/W	Type	Sig Ht	Period Max Energy	
hr:min:sec		ft	ft			ft	sec	
TAPE 4								
0:00	116-119	1.5	24	10.3	Regular	0.5	1.083	
6:15	120,121				Regular	1.0	1.539	
10:30	122,123				Regular	1.5	1.932	
14:36	124,125				Irregular	0.5	1.957	
18:49	126,127				Irregular	0.75	2.397	
23:08	128				Irregular	1.0	2.768	
25:55	129,130				Breaking	1.4	1.5	
30:04	131-134	1.5	24	5.0	Regular	0.5	1.083	
35:59	135,136				Regular	1.0	1.539	
40:11	137-139				Regular	1.5	1.932	Heave 3 broke, Run 138
45:52	140,141				Irregular	0.5	1.957	
50:03	142,143				Irregular	0.75	2.397	
54:20	144				Irregular	1.0	2.768	
56:57	145,146				Breaking	1.4	1.5	
1:00:59	147-149	1	12	9.9	Calm			
1:07:42	150-152				Regular	0.5	1.083	
1:13:44	153,154				Regular	1.0	1.539	
1:18:38	155,156				Regular	1.5	1.932	Heave 0 broke late 156;OK
1:23:49	157,158				Irregular	0.5	1.957	
1:28:50	159,160				Irregular	0.75	2.397	
1:34:07	161				Irregular	1.0	2.768	
1:37:34	162,163				Breaking	1.4	1.5	
1:42:45	164				Regular	0.5	1.083	0 speed data

TABLE 4.1
MODEL ROOT-MEAN-SQUARE MEASUREMENTS
Heave and Wave Height at Corresponding Locations

RUN	Heave0 in	Heave2 in	Heave3 in	Heave4 in	Wave0 in	Wave2 in	Wave3 in	Wave4 in
1	2.605	1.649	0.919	2.041	1.762	1.789	1.840	1.806
2	2.212	1.570	1.071	1.738	1.553	1.537	1.526	1.614
3	2.646	1.426	0.979	1.665	1.666	1.687	1.709	1.748
4	2.167	1.181	0.668	0.716	1.609	1.629	1.683	1.799
5	5.579	4.369	3.513	4.521	3.883	3.998	3.949	3.975
6	5.284	4.240	3.667	4.556	3.839	3.985	4.038	4.129
7	5.481	4.315	3.368	4.568	3.934	4.074	3.975	4.025
8	7.720	6.734	5.864	6.460	6.091	6.201	6.358	6.400
9	7.699	6.778	5.650	6.459	5.882	5.930	6.136	6.096
10	1.763	1.420	1.247	1.537	1.326	1.338	1.360	1.375
11	1.912	1.474	1.403	1.496	1.357	1.395	1.404	1.465
12	4.302	3.516	2.972	3.069	3.190	3.143	3.167	3.059
13	2.706	3.244	2.825	2.268	2.140	2.146	2.223	2.194
14	3.072	2.421	2.180	2.227	2.192	2.229	2.238	2.311
15	3.420	2.424	2.118	2.387	1.877	1.939	2.180	2.166
16	3.068	2.512	2.323	2.591	2.140	2.174	2.214	2.251
17	2.362	1.812	1.613	2.334	1.638	1.744	1.765	1.847
18	2.100	1.526	1.110	1.709	1.480	1.502	1.574	1.684
19	3.015	1.650	0.773	0.719	1.782	1.813	1.904	1.882
20	1.932	1.115	0.735	0.499	1.675	1.744	1.792	1.855
21	5.276	4.054	3.699	4.311	3.735	3.985	4.161	4.126
22	5.667	4.322	3.351	4.345	3.867	4.030	3.994	4.046
23	7.287	6.486	6.107	5.754	6.148	6.118	6.243	6.465
24	7.693	6.699	5.961	5.733	5.748	5.762	6.025	6.235
25	7.816	6.702	5.913	5.684	5.750	5.772	5.980	6.227
26	7.392	6.411	5.955	5.692	6.138	6.087	6.245	6.325
27	1.869	1.482	1.333	1.555	1.341	1.380	1.374	1.400
28	2.041	1.437	1.301	1.241	1.316	1.375	1.411	1.415
29	2.948	2.552	2.157	2.160	2.098	2.121	2.235	2.212
30	3.241	2.419	2.065	1.801	2.275	2.267	2.234	2.332
31	3.547	2.766	2.519	2.695	2.545	2.567	2.655	2.688
32	3.823	2.686	2.163	2.092	2.048	2.113	2.447	2.361
33	2.880	1.766	1.377	2.431	1.616	1.733	1.816	1.909
34	2.177	1.516	1.128	1.698	1.476	1.509	1.498	1.552
35	2.926	1.529	0.847	1.011	1.650	1.698	1.820	1.836
36	1.488	0.798	0.987	0.305	1.646	1.706	1.760	1.854
37	6.267	4.190	3.813	4.136	3.434	3.913	4.131	4.139
38	5.968	4.230	3.410	4.140	3.622	3.914	3.846	3.874
39	7.537	6.434	6.033	5.814	6.048	6.056	6.176	6.475
40	8.945	6.609	5.900	5.553	5.770	5.812	5.991	6.326
41	2.041	1.522	1.358	1.558	1.362	1.402	1.420	1.467
42	2.030	1.510	1.274	1.229	1.302	1.371	1.442	1.463
43	3.430	2.321	2.186	2.289	2.114	2.120	2.222	2.232
44	3.698	2.515	2.128	1.934	2.210	2.221	2.256	2.334
45	4.350	2.848	2.606	2.843	2.601	2.611	2.735	2.763
46	4.514	2.867	2.218	2.148	1.970	2.081	2.486	2.355

TABLE 4.2

MODEL ROOT-MEAN-SQUARE MEASUREMENTS
Heave and Wave Height at Corresponding Locations

RUN	Heave0 in	Heave2 in	Heave3 in	Heave4 in	Wave0 in	Wave2 in	Wave3 in	Wave4 in
50	3.071	1.528	1.414	2.175	1.920	1.842	1.957	1.992
51	2.304	1.512	1.392	1.909	1.634	1.650	1.605	1.594
52	3.201	1.657	1.410	1.760	1.636	1.676	1.655	1.677
53	5.341	2.037	1.420	1.534	1.705	1.690	1.697	1.739
54	5.219	4.567	3.547	3.607	3.935	4.201	4.284	4.125
55	5.250	4.263	3.241	3.720	4.067	4.113	3.990	4.119
56	7.412	7.618	6.565	5.513	6.180	6.151	6.339	6.234
57	8.112	6.709	6.271	5.827	6.045	6.177	6.284	6.292
58	1.762	1.465	1.416	1.610	1.486	1.484	1.474	1.499
59	2.068	1.500	1.388	1.499	1.501	1.519	1.496	1.489
60	3.647	3.382	3.192	2.867	3.216	3.232	3.264	3.132
61	2.777	2.374	2.253	2.263	2.302	2.270	2.306	2.317
62	3.246	2.441	2.301	2.072	2.214	2.249	2.324	2.294
63	3.860	3.019	2.798	2.892	2.744	2.740	2.803	2.830
64	4.434	3.052	2.746	2.607	2.584	2.598	2.668	2.662
65	3.100	1.593	1.542	2.535	1.869	1.909	1.960	1.957
66	2.172	1.467	1.282	1.976	1.498	1.553	1.496	1.524
67	2.588	1.519	1.155	1.702	1.788	1.791	1.713	1.717
68	3.762	1.616	0.904	1.246	1.888	1.886	1.900	1.912
69	5.275	4.032	3.507	4.611	3.871	4.103	4.127	4.123
70	5.345	4.220	3.133	4.516	4.034	4.108	4.052	4.139
71	7.513	6.609	6.164	6.282	6.158	6.195	6.381	6.351
72	7.628	6.695	6.028	6.186	6.065	6.100	6.261	6.224
73	1.850	1.497	1.413	1.766	1.461	1.455	1.454	1.477
74	1.953	1.504	1.365	1.545	1.470	1.510	1.475	1.492
75	2.798	2.331	2.313	2.438	2.280	2.247	2.313	2.322
76	2.868	2.336	2.266	2.258	2.266	2.245	2.315	2.272
77	3.764	3.261	3.223	3.186	3.215	3.232	3.252	3.145
78	3.742	2.965	2.682	3.202	2.834	2.843	2.917	2.931
79	3.880	2.829	2.384	2.546	2.346	2.366	2.452	2.473
80	2.907	1.370	1.029	2.159	1.857	1.886	1.809	1.913
81	2.437	1.552	1.242	2.005	1.659	1.650	1.673	1.679
82	2.899	1.454	1.136	1.799	1.740	1.785	1.765	1.809
83	3.482	1.668	1.214	1.444	1.765	1.768	1.822	1.862
84	5.181	4.084	3.328	4.605	3.992	4.133	4.074	4.165
85	5.223	4.222	3.055	4.482	3.983	4.080	4.027	4.124
86	7.633	6.949	6.165	6.287	6.446	6.468	6.487	6.553
87	7.689	6.917	6.097	6.374	6.038	6.085	6.277	6.430
88	1.821	1.508	1.312	1.732	1.483	1.472	1.484	1.494
89	1.892	1.532	1.335	1.593	1.484	1.522	1.503	1.511
90	2.737	2.410	2.199	2.504	2.330	2.302	2.348	2.354
91	2.685	2.372	2.137	2.353	2.283	2.317	2.306	2.306
92	3.661	3.312	3.069	3.290	3.271	3.286	3.287	3.196
93	3.624	3.073	2.715	3.293	2.875	2.907	2.971	3.033
94	3.786	2.871	2.415	2.577	2.409	2.418	2.542	2.584

TABLE 4.3

MODEL ROOT-MEAN-SQUARE MEASUREMENTS
Heave and Wave Height at Corresponding Locations

RUN	Heave0 in	Heave2 in	Heave3 in	Heave4 in	Wave0 in	Wave2 in	Wave3 in	Wave4 in
99	2.477	1.004	0.503	1.477	1.823	1.808	2.025	1.976
100	1.984	1.384	1.239	1.923	1.549	1.614	1.617	1.705
101	1.990	1.207	0.812	1.194	1.756	1.792	1.825	1.961
102	1.344	1.035	0.942	0.533	1.401	1.449	1.562	1.815
104	5.293	3.927	3.773	4.393	3.653	3.940	4.131	4.416
105	5.873	4.389	3.096	3.716	3.791	3.893	3.928	4.136
106	8.387	6.874	5.791	8.267	6.032	6.119	6.294	6.508
107	8.397	6.966	5.511	6.810	5.759	5.774	6.149	6.198
108	1.849	1.405	1.394	1.577	1.350	1.369	1.402	1.502
109	1.794	1.421	1.194	1.306	1.194	1.233	1.301	1.341
110	2.933	2.594	2.485	2.469	2.253	2.325	2.370	2.367
111	2.854	2.513	2.204	2.612	2.316	2.301	2.354	2.430
112	3.869	3.363	3.026	3.390	3.204	3.187	3.259	3.209
113	3.565	2.842	2.694	3.342	2.544	2.568	2.627	2.677
115	2.767	2.141	1.858	2.152	1.591	1.851	2.220	1.922
116	2.100	1.397	0.822	1.478	1.774	1.844	2.081	2.163
117	2.110	1.218	1.088	1.635	1.524	1.583	1.648	1.776
118	1.655	0.988	0.883	1.000	1.553	1.611	1.669	1.835
119	1.224	0.993	1.136	0.383	1.484	1.583	1.697	1.878
120	5.202	3.705	3.780	4.425	3.489	3.815	4.032	4.368
121	5.542	4.116	3.261	4.195	3.666	3.781	3.945	3.802
122	7.608	6.269	5.784	6.700	5.971	5.982	6.208	6.521
123	8.272	6.758	5.672	6.579	5.568	5.561	5.845	6.160
124	1.777	1.645	1.592	1.540	1.326	1.332	1.385	1.464
125	1.774	1.398	1.305	1.118	1.214	1.254	1.325	1.381
126	2.925	2.327	2.448	2.278	2.315	2.338	2.408	2.415
127	2.780	2.319	2.219	2.068	2.206	2.196	2.244	2.414
128	3.880	3.263	3.130	3.104	3.132	3.142	3.269	3.204
129	3.397	2.578	2.454	2.819	2.367	2.373	2.477	2.654
130	3.161	2.434	2.245	1.948	1.655	2.001	2.495	2.080
131	2.144	1.458	0.911	1.977	1.814	1.862	2.082	2.153
132	1.948	1.223	1.080	1.717	1.434	1.540	1.589	1.695
133	1.684	1.090	1.055	1.108	1.574	1.644	1.765	1.891
134	1.080	0.888	1.157	0.545	1.451	1.529	1.740	1.914
135	5.412	3.713	3.697	4.374	3.472	3.744	4.071	4.494
136	5.855	4.030	3.391	4.153	3.631	3.728	3.865	3.758
137	7.610	6.434	6.031	7.086	5.781	5.785	6.082	6.618
139	8.820	6.814	5.925	6.147	5.256	5.295	5.620	6.179
140	1.820	1.378	1.656	1.620	1.335	1.334	1.373	1.483
141	1.783	1.327	1.365	1.117	1.173	1.211	1.321	1.379
142	3.036	2.354	2.477	2.410	2.257	2.326	2.415	2.415
143	2.910	2.350	2.203	1.956	2.211	2.189	2.268	2.415
144	3.932	3.075	3.097	3.091	3.020	3.001	3.103	3.167
145	3.431	2.528	2.800	2.870	2.351	2.359	2.524	2.676
146	3.152	2.244	2.474	1.795	1.564	2.069	2.517	1.993

TABLE 4.4

MODEL ROOT-MEAN-SQUARE MEASUREMENTS
Heave and Wave Height at Corresponding Locations

RUN	Heave0 in	Heave2 in	Heave3 in	Heave4 in	Wave0 in	Wave2 in	Wave3 in	Wave4 in
164	2.772			2.533	1.947	2.025	1.948	1.923
150	2.307			1.969	1.695	1.733	1.784	1.761
151	2.425			1.617	1.576	1.623	1.754	1.634
152	2.457			1.673	1.750	1.774	1.894	1.852
153	5.243			3.955	3.869	4.032	4.250	4.086
154	5.478			4.011	3.954	4.119	4.382	4.204
155	7.245			5.644	6.067	6.091	6.409	6.174
156	7.517			5.104	5.682	5.763	5.949	5.991
157	1.637			1.517	1.351	1.379	1.435	1.396
158	1.716			1.592	1.290	1.325	1.388	1.406
159	2.689			2.269	2.061	2.092	2.167	2.108
160	2.620			2.402	2.186	2.251	2.337	2.255
161	3.615			3.294	3.064	3.105	3.239	3.143
162	3.610			2.906	2.559	2.617	2.734	2.737
163	3.553			2.153	1.957	2.016	2.245	2.516

TABLE 5.1
1/4-SCALE MODEL HEAVE RESPONSE IN WAVES - 1 Ft x 24 Ft BOOM
RMS Heave/RMS Wave at Corresponding Locations

RUN	0	2	3	4	2Π/Te rad/sec	B/W	Waves ft	Speed fps
1	1.48	0.92	0.50	1.13	5.8	34.3	R 0.5	0
2	1.42	1.02	0.70	1.08	6.2			.427
3	1.59	0.85	0.57	0.95	6.7			.839
4	1.35	0.72	0.40	0.40	7.5			1.663
5	1.44	1.09	0.89	1.14	4.5		R 1.0	.776
6	1.38	1.06	0.91	1.10	4.3			.435
7	1.39	1.06	0.85	1.13	4.5			.803
8	1.27	1.09	0.92	1.01	3.4		R 1.5	.425
9	1.31	1.14	0.92	1.06	3.5			.843
10	1.33	1.06	0.92	1.12	-		I 0.5	.416
11	1.41	1.06	1.00	1.02	-			.867
12	1.35	1.12	0.94	1.00	-		I 1.0	.420
13	1.26	1.51	1.27	1.03	-		I 0.75	.397
14	1.40	1.09	0.97	0.96	-			.829
15	1.82	1.25	0.97	1.10	-		B 1.4	.821
16	1.43	1.16	1.05	1.15	-			.393
17	1.44	1.04	0.91	1.26	5.8	10.4	R 0.5	0
18	1.42	1.02	0.71	1.01	6.2			.416
19	1.69	0.91	0.41	0.38	6.6			.801
20	1.15	0.64	0.41	0.27	7.6			1.691
21	1.41	1.02	0.89	1.04	4.3		R 1.0	.424
22	1.47	1.07	0.84	1.07	4.5			.830
23	1.19	1.06	0.98	0.89	3.4		R 1.5	.394
24	1.34	1.16	0.99	0.92	3.5			.834
25	1.36	1.16	0.99	0.91	3.5			.833
26	1.20	1.05	0.95	0.90	3.4			.440
27	1.39	1.07	0.97	1.11	-		I 0.5	.425
28	1.55	1.05	0.92	0.88	-			.872
29	1.41	1.20	0.97	0.98	-		I 0.75	.396
30	1.42	1.07	0.92	0.77	-			.825
31	1.39	1.08	0.95	1.00	-		B 1.4	.418
32	1.87	1.27	0.88	0.89	-			.824
33	1.78	1.02	0.76	1.27	5.8	4.4	R 0.5	0
34	1.47	1.00	0.75	1.09	6.3			.429
35	1.77	0.90	0.47	0.55	6.6			.798
36	0.90	0.47	0.56	0.16	7.5			1.667
37	1.82	1.07	0.92	1.00	4.3		R 1.0	.407
38	1.65	1.08	0.89	1.07	4.5			.829
39	1.25	1.06	0.98	0.90	3.4		R 1.5	.453
40	1.55	1.14	0.98	0.88	3.5			.824
41	1.50	1.09	0.96	1.06	-		I 0.5	.436
42	1.56	1.10	0.88	0.84	-			.856
43	1.62	1.09	0.98	1.03	-		I 0.75	.392
44	1.67	1.13	0.94	0.83	-			.839
45	1.67	1.09	0.95	1.03	-		B 1.4	.398
46	2.29	1.38	0.89	0.91	-			.841

TABLE 5.2

1/8-SCALE MODEL HEAVE RESPONSE IN WAVES - 0.5 Ft x 24 Ft BOOM
RMS Heave/RMS Wave at Corresponding Locations

RUN	0	2	3	4	2Π/Te rad/sec	B/W	Waves ft	Speed fps
50	1.60	0.83	0.72	1.09	5.8	16.2	R 0.5	0
51	1.41	0.92	0.87	1.20	6.1			.312
52	1.96	0.99	0.85	1.05	6.5			.604
53	3.13	1.21	0.84	0.88	7.0			1.186
54	1.33	1.09	0.83	0.87	4.3		R 1.0	.303
55	1.29	1.04	0.81	0.90	4.4			.601
56	1.20	1.24	1.04	0.88	3.4		R 1.5	.312
57	1.34	1.09	1.00	0.93	3.4			.560
58	1.19	0.99	0.96	1.07	-		I 0.5	.303
59	1.38	0.99	0.93	1.01	-			.602
60	1.13	1.05	0.98	0.92	-		I 1.0	.303
61	1.21	1.05	0.98	0.98	-		I 0.75	.303
62	1.47	1.09	0.99	0.90	-			.601
63	1.41	1.10	1.00	1.02	-		B 1.4	.281
64	1.72	1.17	1.03	0.98	-			.551
65	1.66	0.83	0.79	1.30	5.8	9.6	R 0.5	0
66	1.45	0.94	0.86	1.30	6.1			.304
67	1.45	0.85	0.67	0.99	6.4			.6
68	1.99	0.86	0.48	0.65	7.0			1.182
69	1.36	0.98	0.85	1.12	4.2		R 1.0	.303
70	1.32	1.03	0.77	1.09	4.4			.601
71	1.22	1.07	0.97	0.99	3.4		R 1.5	.303
72	1.26	1.10	0.96	0.99	3.4			.601
73	1.27	1.03	0.97	1.20	-		I 0.5	.303
74	1.33	1.00	0.93	1.04	-			.602
75	1.23	1.04	1.00	1.05	-		I 0.75	.304
76	1.27	1.04	0.98	0.99	-			.587
77	1.17	1.01	0.99	1.01	-		I 1.0	.303
78	1.32	1.04	0.92	1.09	-		B 1.4	.293
79	1.65	1.20	0.97	1.03	-			.610
80	1.57	0.73	0.57	1.13	5.8	12.5	R 0.5	0
81	1.47	0.94	0.74	1.19	6.1			.295
82	1.67	0.81	0.64	0.99	6.4			.604
83	1.97	0.94	0.67	0.78	7.0			1.122
84	1.30	0.99	0.82	1.11	4.2		R 1.0	.302
85	1.31	1.03	0.76	1.09	4.4			.599
86	1.18	1.07	0.95	0.96	3.4		R 1.5	.303
87	1.27	1.14	0.97	0.99	3.4			.566
88	1.23	1.02	0.88	1.16	-		I 0.5	.304
89	1.27	1.01	0.89	1.05	-			.603
90	1.17	1.05	0.94	1.06	-		I 0.75	.303
91	1.18	1.02	0.93	1.02	-			.601
92	1.12	1.01	0.93	1.03	-		I 1.0	.304
93	1.26	1.06	0.91	1.09	-		B 1.4	.277
94	1.57	1.19	0.95	1.00	-			.619

TABLE 5.3

3/8-SCALE MODEL HEAVE RESPONSE IN WAVES - 1.5 Ft x 24 Ft BOOM
RMS Heave/RMS Wave at Corresponding Locations

RUN	0	2	3	4	2Π/Te rad/sec	B/W	Waves ft	Speed fps
99	1.36	0.56	0.25	0.75	5.8	33.6	R 0.5	0
100	1.28	0.86	0.77	1.13	6.3			.489
101	1.13	0.67	0.44	0.61	6.8			.990
102	0.96	0.71	0.60	0.29	8.2			2.265
104	1.45	1.00	0.91	0.99	4.3		R 1.0	.470
105	1.55	1.13	0.79	0.90	4.3			1.084
106	1.39	1.12	0.92	1.27	4.6		R 1.5	.606
107	1.46	1.21	0.90	1.10	3.5			1.046
108	1.37	1.03	0.99	1.05	-		I 0.5	.562
109	1.50	1.15	0.92	0.97	-			1.023
110	1.30	1.12	1.05	1.04	-		I 0.75	.490
111	1.23	1.09	0.94	1.07	-			1.049
112	1.21	1.06	0.93	1.06	-		I 1.0	.509
113	1.40	1.11	1.03	1.25	-		B 1.4	.546
115	1.74	1.16	0.84	1.12	-			1.079
116	1.18	0.76	0.40	0.68	5.8	10.3	R 0.5	0
117	1.38	0.77	0.66	0.92	6.3			.490
118	1.07	0.61	0.53	0.54	6.9			1.029
119	0.82	0.63	0.67	0.20	7.8			1.950
120	1.49	0.97	0.94	1.01	4.3		R 1.0	.504
121	1.51	1.09	0.83	1.10	4.6			1.040
122	1.27	1.05	0.93	1.03	3.4		R 1.5	.559
123	1.49	1.22	0.97	1.07	3.6			1.007
124	1.34	1.23	1.15	1.05	-		I 0.5	.504
125	1.46	1.11	0.98	0.81	-			1.022
126	1.26	1.00	1.02	0.94	-		I 0.75	.503
127	1.26	1.06	0.99	0.86	-			1.020
128	1.24	1.04	0.96	0.97	-		I 1.0	.502
129	1.44	1.09	0.99	1.06	-		B 1.4	.516
130	1.91	1.22	0.90	0.94	-			1.023
131	1.18	0.78	0.44	0.92	5.8	5.0	R 0.5	0
132	1.36	0.79	0.68	1.01	6.3			.503
133	1.07	0.66	0.60	0.59	6.9			1.037
134	0.74	0.58	0.66	0.28	7.8			1.928
135	1.56	0.99	0.91	0.97	4.4		R 1.0	.541
136	1.61	1.08	0.88	1.11	4.6			1.019
137	1.32	1.11	0.99	1.07	3.4		R 1.5	.546
139	1.68	1.29	1.05	0.99	3.6			1.013
140	1.36	1.03	1.21	1.09	-		R 0.5	.527
141	1.52	1.10	1.03	0.81	-			1.039
142	1.35	1.01	1.03	1.00	-		I 0.75	.501
143	1.32	1.07	0.97	0.81	-			1.028
144	1.30	1.02	1.00	0.98	-		I 1.0	.538
145	1.46	1.07	1.11	1.07	-		B 1.4	.538
146	2.02	1.08	0.98	0.90	-			1.029

TABLE 5.4

1/4-SCALE MODEL HEAVE RESPONSE IN WAVES - 1 Ft x 12 Ft BOOM
RMS Heave/RMS Wave at Corresponding Locations

RUN	0	2	3	4	2Π/Te rad/sec	B/W	Waves ft	Speed fps
164	1.42	-	-	1.32	5.8	9.9	R 0.5	0
150	1.36	-	-	1.12	6.3			.470
151	1.54	-	-	0.99	6.6			.769
152	1.40	-	-	0.90	7.5			1.577
153	1.36	-	-	0.97	4.3		R 1.0	.469
154	1.39	-	-	0.95	4.5			.805
155	1.19	-	-	0.91	3.4		R 1.5	.429
156	1.32	-	-	0.85	3.5			.850
157	1.21	-	-	1.09	-		I 0.5	.433
158	1.33	-	-	1.13	-			.829
159	1.30	-	-	1.08	-		I 0.75	.421
160	1.20	-	-	1.07	-			.850
161	1.18	-	-	1.05	-		I 1.0	.417
162	1.41	-	-	1.06	-		B 1.4	.425
163	1.82	-	-	0.86	-			.847

TABLE 6.1

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 16.2
Waves 0.50 ft Significant Height

Run(s) : 58, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.611	177	2.69	4.48	5.64	6.37
	1.762	0.30	-1.34	-2.67	-3.48	-5.53
Heave 2, in	-0.141	147	1.59	2.94	3.76	4.30
	1.465	0.30	-1.84	-3.00	-3.76	-4.96
Heave 3, in	0.480	148	2.25	3.60	4.48	5.97
	1.416	0.30	-1.12	-2.16	-2.80	-3.43
Heave 4, in	-0.068	178	1.83	3.16	3.95	4.74
	1.610	0.30	-1.88	-3.22	-4.22	-5.76
Wave 0, in	-0.372	168	1.54	2.92	3.79	4.31
	1.486	0.30	-1.92	-3.17	-3.95	-5.72
Wave 2, in	-0.257	170	1.55	2.90	3.78	4.69
	1.484	0.30	-1.87	-3.11	-3.84	-5.36
Wave 3, in	-0.255	174	1.49	2.93	3.87	6.04
	1.474	0.30	-1.82	-3.01	-3.78	-4.34
Wave 4, in	-0.348	175	1.49	2.79	3.81	5.27
	1.499	0.30	-1.87	-3.19	-3.99	-5.03

TABLE 6.2

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 16.2
Waves 0.50 ft Significant Height

Run(s) : 59, Speed 0.602 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.832	97	3.13	4.79	6.44	7.85
	2.068	0.30	-1.34	-3.13	-5.13	-10.40
Heave 2, in	0.059	77	1.84	3.20	4.41	5.28
	1.500	0.30	-1.63	-2.92	-3.84	-5.01
Heave 3, in	0.343	77	2.07	3.29	4.29	5.28
	1.388	0.30	-1.22	-2.31	-2.89	-3.54
Heave 4, in	0.207	100	1.81	3.11	4.00	4.71
	1.499	0.30	-1.44	-2.62	-3.32	-4.06
Wave 0, in	-0.401	89	1.40	2.73	4.17	5.38
	1.501	0.30	-2.07	-3.28	-4.06	-4.59
Wave 2, in	-0.279	84	1.64	2.96	4.31	5.80
	1.519	0.30	-1.98	-3.07	-3.59	-4.16
Wave 3, in	-0.285	83	1.68	2.99	3.95	4.55
	1.496	0.30	-1.99	-3.20	-3.93	-4.30
Wave 4, in	-0.406	88	1.47	2.72	3.60	4.31
	1.489	0.30	-2.04	-3.27	-4.18	-4.92

TABLE 6.3

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 16.2
Waves 0.75 ft Significant Height

Run(s) : 61, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.702	160	3.77	6.57	8.41	11.51
	2.777	0.30	-1.88	-4.12	-6.25	-14.60
Heave 2, in	-0.035	127	2.79	4.91	6.40	8.36
	2.374	0.30	-2.58	-4.25	-5.87	-9.86
Heave 3, in	0.308	126	3.07	5.14	6.67	9.49
	2.253	0.30	-2.12	-3.78	-5.41	-8.57
Heave 4, in	-0.140	171	2.20	4.26	5.50	7.88
	2.263	0.30	-2.41	-4.39	-5.74	-9.55
Wave 0, in	-0.385	141	2.42	4.59	6.14	7.98
	2.302	0.30	-2.74	-4.43	-5.83	-9.28
Wave 2, in	-0.273	138	2.57	4.75	6.46	9.66
	2.270	0.30	-2.61	-4.37	-5.86	-9.10
Wave 3, in	-0.275	146	2.40	4.49	6.50	10.13
	2.306	0.30	-2.50	-4.42	-5.62	-9.05
Wave 4, in	-0.374	142	2.49	4.52	6.36	9.95
	2.317	0.30	-2.74	-4.62	-6.06	-8.76

TABLE 6.4

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 16.2
Waves 0.75 ft Significant Height

Run(s) : 62, Speed 0.601 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.517	85	3.75	6.43	8.18	11.40
	3.246	0.30	-2.21	-5.12	-9.80	-17.95
Heave 2, in	0.434	66	3.22	5.32	6.88	9.18
	2.441	0.30	-2.19	-3.96	-6.04	-11.28
Heave 3, in	-0.100	65	2.65	4.68	6.62	10.30
	2.301	0.30	-2.58	-4.20	-5.68	-8.23
Heave 4, in	0.539	94	2.47	4.22	5.58	6.92
	2.072	0.30	-1.53	-3.52	-4.91	-7.29
Wave 0, in	-0.293	76	2.22	4.52	6.12	8.85
	2.214	0.30	-2.53	-4.12	-5.47	-9.26
Wave 2, in	-0.150	71	2.57	4.66	6.20	8.62
	2.249	0.30	-2.49	-4.11	-5.24	-8.78
Wave 3, in	-0.198	72	2.65	4.70	6.40	10.23
	2.324	0.30	-2.62	-4.47	-5.77	-9.48
Wave 4, in	-0.353	75	2.30	4.20	5.90	10.69
	2.294	0.30	-2.69	-4.58	-5.92	-8.29

TABLE 6.5

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 16.2
Waves 1.00 ft Significant Height

Run(s) : 60, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.162	139	4.11	7.39	9.49	11.64
	3.647	0.30	-3.31	-6.33	-9.00	-15.03
Heave 2, in	-0.274	112	3.92	6.77	8.54	10.86
	3.382	0.30	-4.03	-6.70	-8.43	-10.15
Heave 3, in	0.233	119	4.10	6.90	8.80	10.78
	3.192	0.30	-2.98	-5.63	-7.36	-9.07
Heave 4, in	-0.306	145	2.79	5.26	6.44	8.11
	2.867	0.30	-3.22	-5.63	-7.04	-8.60
Wave 0, in	-0.432	132	3.37	6.27	7.93	9.59
	3.216	0.30	-3.57	-6.23	-7.68	-9.25
Wave 2, in	-0.311	127	3.55	6.49	8.34	10.07
	3.232	0.30	-3.56	-6.16	-7.80	-10.13
Wave 3, in	-0.318	128	3.61	6.55	8.30	9.80
	3.264	0.30	-3.56	-6.30	-7.93	-8.99
Wave 4, in	-0.406	126	3.61	6.30	7.83	9.52
	3.132	0.30	-3.63	-6.05	-7.74	-8.95

TABLE 6.6

MODEL BREAKING WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W - 16.2
Waves 1.4 ft Significant Height

Run(s) : 63, Speed 0.281 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.192	153	5.03	8.75	11.17	13.58
	3.860	0.30	-3.61	-6.82	-11.04	-15.35
Heave 2, in	-0.097	151	3.71	6.45	8.37	9.65
	3.019	0.30	-3.48	-5.80	-6.89	-9.23
Heave 3, in	-0.221	151	3.46	6.07	7.91	9.29
	2.798	0.30	-3.42	-5.60	-6.68	-8.48
Heave 4, in	-0.041	160	3.59	5.66	6.51	7.64
	2.892	0.30	-3.45	-5.77	-7.61	-9.62
Wave 0, in	-0.266	152	3.64	6.26	8.38	10.38
	2.744	0.30	-3.44	-5.29	-6.72	-7.55
Wave 2, in	-0.137	152	3.76	6.43	8.42	10.09
	2.740	0.30	-3.30	-5.17	-6.51	-7.58
Wave 3, in	-0.165	152	3.82	6.54	8.49	10.21
	2.803	0.30	-3.36	-5.36	-6.66	-7.42
Wave 4, in	-0.295	154	3.67	6.45	8.69	10.30
	2.830	0.30	-3.53	-5.55	-6.79	-8.04

TABLE 6.7

MODEL BREAKING WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 16.2
Waves 1.4 ft Significant Height

Run(s) : 64, Speed 0.551 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.304	79	4.74	8.53	11.00	13.25
	4.434	0.30	-3.78	-9.12	-17.03	-18.31
Heave 2, in	-0.168	75	3.54	6.46	8.71	10.34
	3.052	0.30	-3.39	-6.42	-9.63	-11.19
Heave 3, in	-0.409	73	3.01	6.03	8.13	9.36
	2.746	0.30	-3.69	-5.93	-6.86	-7.34
Heave 4, in	0.216	83	3.19	5.46	6.34	6.71
	2.607	0.30	-2.82	-5.38	-7.43	-9.04
Wave 0, in	-0.306	77	3.19	6.21	8.22	9.73
	2.584	0.30	-3.17	-5.43	-7.07	-7.67
Wave 2, in	-0.176	77	3.35	6.46	8.61	10.74
	2.598	0.30	-3.03	-5.35	-6.93	-7.65
Wave 3, in	-0.224	78	3.42	6.44	8.62	10.33
	2.668	0.30	-3.12	-5.41	-6.81	-7.59
Wave 4, in	-0.358	77	3.30	6.31	8.34	9.81
	2.662	0.30	-3.32	-5.64	-6.70	-7.08

TABLE 6.8

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 12.5
Waves 0.50 ft Significant Height

Run(s) : 88, Speed 0.304 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.145	180	2.26	3.95	5.04	6.05
	1.821	0.30	-1.90	-3.39	-4.32	-5.23
Heave 2, in	1.573	152	3.37	4.72	5.56	6.10
	1.508	0.30	-0.17	-1.43	-2.20	-3.74
Heave 3, in	1.200	140	2.84	4.13	4.80	5.59
	1.312	0.30	-0.31	-1.31	-1.91	-2.49
Heave 4, in	0.689	172	2.65	4.32	5.30	6.77
	1.732	0.30	-1.24	-2.63	-3.55	-4.37
Wave 0, in	-0.191	166	1.65	2.92	3.87	5.02
	1.483	0.30	-1.81	-3.07	-3.85	-5.09
Wave 2, in	-0.049	164	1.81	3.22	4.04	4.59
	1.472	0.30	-1.66	-2.81	-3.62	-5.24
Wave 3, in	-0.097	170	1.70	3.13	4.01	5.29
	1.484	0.30	-1.68	-2.90	-3.53	-4.88
Wave 4, in	-0.238	170	1.61	3.01	3.91	5.29
	1.494	0.30	-1.84	-3.07	-3.83	-4.59

TABLE 6.9

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 12.5
Waves 0.50 ft Significant Height

Run(s) : 89, Speed 0.603 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.157	93	2.48	4.10	5.33	6.45
	1.892	0.30	-1.93	-3.40	-4.47	-5.45
Heave 2, in	1.727	80	3.51	4.86	5.97	6.64
	1.532	0.30	-0.05	-1.30	-2.10	-2.39
Heave 3, in	1.145	74	2.81	3.96	4.84	5.89
	1.335	0.30	-0.35	-1.47	-2.05	-2.73
Heave 4, in	0.893	95	2.63	4.12	5.21	5.79
	1.593	0.30	-0.95	-2.16	-2.88	-4.20
Wave 0, in	-0.195	86	1.70	2.99	3.95	4.54
	1.484	0.30	-1.76	-2.95	-3.86	-5.03
Wave 2, in	-0.044	86	1.80	3.22	4.47	6.09
	1.522	0.30	-1.77	-2.95	-3.72	-4.23
Wave 3, in	-0.108	85	1.80	3.15	4.25	5.58
	1.503	0.30	-1.83	-2.96	-3.44	-3.92
Wave 4, in	-0.269	90	1.54	2.80	3.71	4.30
	1.511	0.30	-1.88	-3.19	-4.14	-5.09

TABLE 6.10

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 12.5
Waves 0.75 ft Significant Height

Run(s) : 90, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.101	161	3.22	6.19	8.23	10.84
	2.737	0.30	-2.44	-4.60	-6.34	-10.99
Heave 2, in	1.450	128	4.39	6.58	8.07	9.88
	2.410	0.30	-1.19	-3.03	-4.60	-8.05
Heave 3, in	0.934	121	3.69	5.74	7.55	10.40
	2.199	0.30	-1.48	-3.13	-4.56	-6.64
Heave 4, in	0.642	159	3.34	5.74	7.55	10.08
	2.504	0.30	-1.94	-3.98	-5.46	-8.26
Wave 0, in	-0.198	145	2.54	4.80	6.33	8.26
	2.330	0.30	-2.54	-4.27	-5.79	-9.21
Wave 2, in	-0.060	145	2.70	4.93	6.49	8.40
	2.302	0.30	-2.32	-4.14	-5.51	-9.05
Wave 3, in	-0.096	145	2.73	4.80	6.67	10.15
	2.348	0.30	-2.44	-4.38	-5.74	-9.10
Wave 4, in	-0.242	146	2.58	4.69	6.55	9.94
	2.354	0.30	-2.59	-4.56	-6.04	-9.08

TABLE 6.11

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 12.5
Waves 0.75 ft Significant Height

Run(s) : 91, Speed 0.601 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.041	87	3.15	6.02	7.90	10.03
	2.685	0.30	-2.42	-4.58	-5.99	-9.39
Heave 2, in	1.565	72	4.30	6.66	8.40	11.62
	2.372	0.30	-0.95	-2.64	-4.06	-7.76
Heave 3, in	0.973	64	3.66	5.76	7.27	10.51
	2.137	0.30	-1.28	-2.69	-4.21	-8.21
Heave 4, in	0.807	87	3.15	5.65	7.11	8.27
	2.353	0.30	-1.69	-3.59	-4.97	-6.64
Wave 0, in	-0.231	75	2.38	4.33	5.63	8.25
	2.283	0.30	-2.56	-4.34	-5.67	-8.69
Wave 2, in	-0.074	75	2.69	4.99	6.91	10.38
	2.317	0.30	-2.48	-4.23	-5.71	-8.94
Wave 3, in	-0.150	78	2.56	4.85	6.84	10.11
	2.306	0.30	-2.34	-4.13	-5.68	-9.60
Wave 4, in	-0.292	75	2.38	4.38	5.76	6.42
	2.306	0.30	-2.52	-4.30	-5.57	-6.73

TABLE 6.12

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 12.5
Waves 1.00 ft Significant Height

Run(s) : 92, Speed 0.304 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.025	133	4.28	7.69	9.54	11.56
	3.661	0.30	-3.58	-6.55	-8.57	-11.63
Heave 2, in	1.439	113	5.52	8.27	9.74	10.22
	3.312	0.30	-2.25	-4.85	-6.40	-7.18
Heave 3, in	0.653	114	4.39	7.05	8.59	10.43
	3.069	0.30	-2.58	-5.08	-6.86	-7.93
Heave 4, in	0.557	143	4.12	7.32	8.95	10.73
	3.290	0.30	-2.88	-5.40	-7.11	-8.36
Wave 0, in	-0.233	131	3.61	6.63	8.36	9.37
	3.271	0.30	-3.40	-6.14	-7.62	-9.47
Wave 2, in	-0.078	126	3.97	6.78	8.79	11.03
	3.286	0.30	-3.27	-6.00	-7.79	-10.00
Wave 3, in	-0.124	133	3.60	6.63	8.29	9.79
	3.287	0.30	-3.33	-6.11	-7.76	-9.25
Wave 4, in	-0.261	128	3.75	6.61	8.41	9.36
	3.196	0.30	-3.48	-6.00	-7.83	-9.13

TABLE 6.13

MODEL BREAKING WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 12.5
Waves 1.4 ft Significant Height

Run(s) : 93, SPEED 0.277 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.119	144	4.83	8.16	9.91	11.89
	3.624	0.30	-3.99	-7.01	-9.81	-12.83
Heave 2, in	1.010	133	5.14	7.93	9.39	10.21
	3.073	0.30	-2.75	-4.87	-6.03	-7.56
Heave 3, in	0.425	140	3.93	6.75	8.58	10.36
	2.715	0.30	-2.82	-4.32	-5.21	-6.67
Heave 4, in	0.237	145	4.55	7.25	8.16	9.20
	3.293	0.30	-3.61	-5.81	-7.26	-8.67
Wave 0, in	-0.233	134	3.98	6.65	8.88	10.43
	2.875	0.30	-3.64	-5.61	-6.98	-8.29
Wave 2, in	-0.087	135	4.12	6.90	9.36	10.88
	2.907	0.30	-3.49	-5.44	-6.84	-8.16
Wave 3, in	-0.124	135	4.20	6.94	9.32	10.87
	2.971	0.30	-3.58	-5.65	-6.98	-8.08
Wave 4, in	-0.266	135	4.09	7.11	9.04	10.31
	3.033	0.30	-3.81	-5.99	-7.50	-8.17

TABLE 6.14

MODEL BREAKING WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 12.5
Waves 1.4 ft Significant Height

Run(s) : 94, Speed 0.619 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.397	70	3.92	7.50	9.86	12.02
	3.786	0.30	-4.12	-8.38	-14.25	-17.74
Heave 2, in	1.269	60	5.07	7.74	9.94	10.25
	2.871	0.30	-2.34	-5.38	-8.37	-9.90
Heave 3, in	0.732	66	3.78	6.65	9.00	10.32
	2.415	0.30	-2.12	-4.32	-5.56	-7.58
Heave 4, in	0.686	81	3.46	6.32	7.69	8.49
	2.577	0.30	-2.22	-4.63	-5.66	-6.65
Wave 0, in	-0.203	67	3.03	6.00	8.32	10.94
	2.409	0.30	-2.85	-5.16	-6.77	-7.60
Wave 2, in	-0.056	67	3.16	6.16	8.45	10.83
	2.418	0.30	-2.71	-5.10	-6.65	-7.42
Wave 3, in	-0.105	68	3.22	6.23	8.81	10.36
	2.542	0.30	-2.91	-5.35	-6.73	-7.12
Wave 4, in	-0.285	71	3.09	6.28	8.79	10.00
	2.584	0.30	-3.05	-5.52	-6.87	-8.64

TABLE 6.15

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 9.6
Waves 0.50 ft Significant Height

Run(s) : 73, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.045	185	2.20	3.88	4.90	6.11
	1.850	0.30	-2.01	-3.52	-4.47	-5.43
Heave 2, in	1.457	152	3.28	4.55	5.36	5.91
	1.497	0.30	-0.33	-1.55	-2.27	-3.68
Heave 3, in	0.892	147	2.63	3.93	4.72	5.62
	1.413	0.30	-0.71	-1.74	-2.36	-2.96
Heave 4, in	0.403	174	2.38	3.99	4.96	6.67
	1.766	0.30	-1.61	-3.05	-4.06	-5.15
Wave 0, in	-0.258	166	1.52	2.71	3.53	4.79
	1.461	0.30	-1.89	-3.11	-3.87	-5.18
Wave 2, in	-0.133	165	1.67	2.92	3.88	4.37
	1.455	0.30	-1.73	-2.96	-3.80	-4.98
Wave 3, in	-0.142	169	1.60	3.04	4.04	5.00
	1.454	0.30	-1.71	-2.86	-3.44	-4.85
Wave 4, in	-0.235	169	1.56	2.97	3.91	5.36
	1.477	0.30	-1.83	-3.02	-3.80	-4.59

TABLE 6.16

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 9.6
Waves 0.50 ft Significant Height

Run(s) : 74, Speed 0.602 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.007	95	2.29	4.10	5.45	6.02
	1.953	0.30	-2.21	-3.70	-4.66	-5.46
Heave 2, in	1.519	79	3.34	4.64	5.83	6.45
	1.504	0.30	-0.25	-1.42	-2.15	-2.46
Heave 3, in	0.920	76	2.59	3.89	4.80	5.73
	1.365	0.30	-0.62	-1.60	-2.19	-2.43
Heave 4, in	0.619	96	2.25	3.60	4.71	5.35
	1.545	0.30	-1.18	-2.30	-3.17	-4.34
Wave 0, in	-0.308	88	1.51	2.78	4.00	5.16
	1.470	0.30	-1.89	-3.09	-3.91	-4.46
Wave 2, in	-0.174	88	1.61	2.99	4.29	6.25
	1.510	0.30	-1.92	-3.09	-3.77	-4.49
Wave 3, in	-0.199	86	1.69	2.98	4.07	4.74
	1.475	0.30	-1.81	-2.96	-3.56	-3.84
Wave 4, in	-0.315	90	1.49	2.75	3.63	4.38
	1.492	0.30	-1.92	-3.23	-4.14	-4.94

TABLE 6.17

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 9.6
Waves 0.75 ft Significant Height

Run(s) : 75, Speed 0.304 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.020	160	3.13	6.08	8.00	10.06
	2.798	0.30	-2.66	-4.78	-6.76	-15.12
Heave 2, in	1.423	128	4.26	6.42	8.08	9.97
	2.331	0.30	-1.14	-2.84	-4.47	-8.11
Heave 3, in	0.666	130	3.48	5.60	7.41	10.57
	2.313	0.30	-1.88	-3.51	-4.79	-7.32
Heave 4, in	0.677	168	3.17	5.54	7.40	9.88
	2.438	0.30	-1.72	-3.70	-4.98	-7.61
Wave 0, in	-0.331	143	2.41	4.62	6.00	8.12
	2.280	0.30	-2.61	-4.35	-5.75	-8.95
Wave 2, in	-0.203	146	2.45	4.69	6.20	8.57
	2.247	0.30	-2.41	-4.21	-5.49	-8.70
Wave 3, in	-0.251	147	2.49	4.56	6.55	10.55
	2.313	0.30	-2.50	-4.42	-5.75	-9.30
Wave 4, in	-0.389	147	2.35	4.43	6.36	9.55
	2.322	0.30	-2.69	-4.63	-6.10	-8.89

TABLE 6.18

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 9.6
Waves 0.75 ft Significant Height

Run(s) : 76, Speed 0.587 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.159	75	3.32	5.58	7.62	10.74
	2.868	0.30	-3.08	-5.47	-8.12	-14.78
Heave 2, in	1.433	67	4.19	6.10	7.98	10.67
	2.336	0.30	-1.19	-2.96	-4.36	-7.75
Heave 3, in	0.725	65	3.57	5.34	7.13	11.28
	2.266	0.30	-1.79	-3.51	-5.04	-6.77
Heave 4, in	0.827	88	2.99	5.28	6.92	11.36
	2.258	0.30	-1.55	-3.40	-5.13	-7.20
Wave 0, in	-0.338	70	2.45	4.43	6.09	8.85
	2.266	0.30	-2.84	-4.56	-5.64	-8.54
Wave 2, in	-0.206	70	2.57	4.42	6.28	10.12
	2.245	0.30	-2.68	-4.41	-5.54	-8.53
Wave 3, in	-0.259	73	2.55	4.50	6.18	10.05
	2.315	0.30	-2.67	-4.56	-5.84	-8.83
Wave 4, in	-0.389	75	2.32	4.14	5.77	11.35
	2.272	0.30	-2.74	-4.56	-6.20	-7.25

TABLE 6.19

MODEL IRREGULAR WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 9.6
Waves 1.00 ft Significant Height

Run(s) : 77, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.097	136	4.15	7.49	9.66	10.90
	3.764	0.30	-3.66	-6.72	-8.87	-12.11
Heave 2, in	1.402	116	5.38	8.18	9.93	10.97
	3.261	0.30	-2.09	-4.64	-6.25	-7.13
Heave 3, in	0.671	118	4.58	7.47	9.20	10.67
	3.223	0.30	-2.84	-5.49	-7.06	-8.53
Heave 4, in	0.654	147	4.15	7.16	8.70	10.68
	3.186	0.30	-2.65	-5.15	-6.62	-8.48
Wave 0, in	-0.318	131	3.45	6.47	8.20	9.20
	3.215	0.30	-3.52	-6.08	-7.64	-8.70
Wave 2, in	-0.174	129	3.72	6.61	8.50	10.20
	3.232	0.30	-3.34	-5.92	-7.62	-9.69
Wave 3, in	-0.232	127	3.63	6.64	8.35	9.95
	3.252	0.30	-3.53	-6.19	-7.97	-9.39
Wave 4, in	-0.373	126	3.53	6.34	7.83	9.02
	3.145	0.30	-3.65	-6.09	-7.71	-9.56

TABLE 6.20

MODEL BREAKING WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 9.6
Waves 1.4 ft Significant Height

Run(s) : 78, Speed 0.293 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.227	148	4.92	8.05	9.67	12.05
	3.742	0.30	-4.19	-7.47	-11.10	-15.50
Heave 2, in	1.030	142	4.92	7.48	8.81	9.85
	2.965	0.30	-2.53	-4.74	-6.10	-8.75
Heave 3, in	0.416	149	4.01	6.57	8.34	9.49
	2.682	0.30	-2.73	-4.34	-5.22	-6.66
Heave 4, in	0.077	148	4.32	7.02	8.01	8.79
	3.202	0.30	-3.71	-5.87	-7.20	-9.53
Wave 0, in	-0.259	142	3.89	6.64	8.89	9.98
	2.834	0.30	-3.64	-5.51	-6.81	-8.05
Wave 2, in	-0.129	146	3.87	6.74	9.08	11.04
	2.843	0.30	-3.49	-5.36	-6.61	-7.62
Wave 3, in	-0.191	146	3.97	6.72	8.75	9.90
	2.917	0.30	-3.61	-5.67	-6.97	-7.84
Wave 4, in	-0.341	143	3.92	6.82	8.87	10.23
	2.931	0.30	-3.82	-5.93	-7.14	-8.15

TABLE 6.21

MODEL BREAKING WAVE TEST RESULTS
Boom 0.5 x 24 ft B/W = 9.6
Waves 1.4 ft Significant Height

Run(s) : 79, Speed 0.610 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.557	72	3.79	7.27	9.88	12.15
	3.880	0.30	-4.12	-8.78	-15.28	-18.20
Heave 2, in	1.336	58	5.21	7.79	9.43	9.90
	2.829	0.30	-2.34	-5.55	-8.87	-9.42
Heave 3, in	0.598	58	4.29	7.01	8.84	9.52
	2.384	0.30	-2.43	-4.41	-5.72	-6.77
Heave 4, in	0.640	78	3.44	6.41	7.69	8.27
	2.546	0.30	-2.19	-4.52	-6.05	-6.63
Wave 0, in	-0.185	67	2.88	5.71	7.66	9.77
	2.346	0.30	-2.78	-5.14	-6.71	-7.21
Wave 2, in	-0.050	69	3.00	5.82	8.14	9.94
	2.366	0.30	-2.55	-4.96	-6.65	-7.53
Wave 3, in	-0.121	69	3.09	5.99	8.47	9.99
	2.452	0.30	-2.77	-5.15	-6.61	-7.39
Wave 4, in	-0.282	65	3.15	6.34	8.90	9.68
	2.473	0.30	-3.15	-5.57	-6.80	-7.79

TABLE 6.22

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 34.3
Waves 0.50 ft Significant Height

Run(s) : 10, Speed 0.416 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.228	126	2.24	3.71	4.61	5.51
	1.763	0.30	-1.81	-3.31	-4.36	-5.95
Heave 2, in	0.145	112	1.90	3.08	3.75	4.76
	1.420	0.30	-1.50	-2.76	-3.63	-4.64
Heave 3, in	0.580	102	2.15	3.08	3.61	4.41
	1.247	0.30	-0.86	-1.89	-2.49	-2.74
Heave 4, in	1.336	124	3.15	4.32	5.20	6.70
	1.537	0.30	-0.48	-1.62	-2.39	-2.88
Wave 0, in	-0.320	126	1.32	2.47	3.23	4.60
	1.326	0.30	-1.78	-2.82	-3.51	-4.39
Wave 2, in	-0.225	130	1.39	2.56	3.41	5.97
	1.338	0.30	-1.70	-2.72	-3.32	-4.18
Wave 3, in	-0.218	131	1.45	2.62	3.46	5.65
	1.360	0.30	-1.64	-2.74	-3.20	-3.90
Wave 4, in	-0.291	131	1.37	2.63	3.44	4.81
	1.375	0.30	-1.78	-2.87	-3.71	-4.69

TABLE 6.23

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 34.3
Waves 0.50 ft Significant Height

Run(s) : 11, Speed 0.867 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.115	65	2.33	3.64	4.64	5.28
	1.912	0.30	-2.05	-3.77	-5.27	-5.92
Heave 2, in	-0.217	56	1.54	2.83	3.86	4.60
	1.474	0.30	-1.92	-3.22	-4.26	-5.01
Heave 3, in	0.230	51	1.97	3.11	3.94	4.67
	1.403	0.30	-1.40	-2.60	-3.42	-4.13
Heave 4, in	1.793	69	3.30	4.38	5.10	5.71
	1.496	0.30	0.16	-1.31	-2.84	-4.80
Wave 0, in	-0.396	66	1.16	2.21	3.13	4.21
	1.357	0.30	-1.82	-2.98	-3.78	-3.98
Wave 2, in	-0.297	63	1.36	2.46	3.45	5.03
	1.395	0.30	-1.87	-3.02	-3.69	-3.91
Wave 3, in	-0.303	67	1.41	2.73	3.71	4.36
	1.404	0.30	-1.74	-2.78	-3.63	-4.13
Wave 4, in	-0.387	69	1.32	2.46	3.42	3.73
	1.465	0.30	-1.87	-3.10	-4.16	-5.32

TABLE 6.24

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 34.3
Waves 0.75 ft Significant Height

Run(s) : 13, Speed 0.397 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.022	109	3.11	5.42	7.11	11.28
	2.706	0.30	-2.91	-5.07	-6.77	-10.79
Heave 2, in	-0.529	102	2.15	4.67	6.41	11.09
	3.244	0.30	-3.04	-5.81	-10.30	-15.52
Heave 3, in	0.186	95	2.85	4.98	6.60	12.10
	2.825	0.30	-2.19	-4.75	-8.73	-13.26
Heave 4, in	0.951	124	3.29	5.46	7.02	11.44
	2.268	0.30	-1.32	-3.36	-5.27	-8.82
Wave 0, in	-0.319	109	2.28	4.40	6.16	13.01
	2.140	0.30	-2.51	-4.07	-5.19	-7.47
Wave 2, in	-0.233	103	2.52	4.51	6.42	12.80
	2.146	0.30	-2.58	-4.18	-5.27	-7.38
Wave 3, in	-0.227	110	2.50	4.43	6.07	12.24
	2.223	0.30	-2.43	-4.16	-5.51	-7.06
Wave 4, in	-0.321	108	2.43	4.34	6.00	11.34
	2.194	0.30	-2.60	-4.25	-5.62	-8.50

TABLE 6.25

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 34.3
Waves 0.75 ft Significant Height

Run(s) : 14, Speed 0.821 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.049	58	3.39	5.80	7.59	11.04
	3.072	0.30	-2.81	-5.57	-8.90	-18.60
Heave 2, in	-0.187	47	2.77	4.66	6.90	10.34
	2.421	0.30	-2.90	-4.90	-6.99	-11.82
Heave 3, in	0.322	42	3.18	4.72	6.64	10.19
	2.180	0.30	-2.51	-4.02	-5.69	-7.51
Heave 4, in	2.008	66	3.99	5.82	7.09	7.58
	2.227	0.30	-0.20	-2.36	-4.17	-8.00
Wave 0, in	-0.389	52	2.40	4.12	5.78	8.48
	2.192	0.30	-2.55	-4.38	-5.60	-8.36
Wave 2, in	-0.284	53	2.39	4.28	6.19	9.82
	2.229	0.30	-2.65	-4.34	-5.54	-8.52
Wave 3, in	-0.301	49	2.50	4.17	6.30	10.27
	2.238	0.30	-2.84	-4.49	-6.08	-8.33
Wave 4, in	-0.354	50	2.71	4.58	6.21	10.93
	2.311	0.30	-2.70	-4.67	-6.31	-7.63

TABLE 6.26

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 34.3
Waves 1.00 ft Significant Height

Run(s) : 12, Speed 0.42 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.050	22	3.70	7.93	10.03	10.30
	4.302	0.30	-4.80	-9.00	-12.31	-12.47
Heave 2, in	-0.536	20	3.72	7.63	8.70	8.95
	3.516	0.30	-3.85	-7.24	-8.18	-8.50
Heave 3, in	0.325	18	4.19	6.96	7.67	7.67
	2.972	0.30	-2.86	-4.85	-5.97	-5.97
Heave 4, in	0.449	25	3.82	7.35	8.30	8.65
	3.069	0.30	-2.53	-4.82	-6.62	-7.04
Wave 0, in	-0.277	22	3.39	6.64	8.02	8.32
	3.190	0.30	-3.61	-6.06	-7.44	-7.73
Wave 2, in	-0.174	20	3.65	6.97	7.75	7.80
	3.143	0.30	-3.57	-6.17	-7.22	-7.90
Wave 3, in	-0.174	19	3.93	6.99	7.99	7.99
	3.167	0.30	-3.70	-5.86	-6.74	-6.74
Wave 4, in	-0.213	21	3.73	7.36	8.17	8.49
	3.059	0.30	-3.05	-5.58	-7.20	-7.21

TABLE 6.27

MODEL BREAKING WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 34.3
Waves 1.4 ft Significant Height

Run(s) : 16, Speed 0.393 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.170	114	2.96	6.95	9.86	12.13
	3.068	0.30	-2.87	-6.83	-9.29	-13.37
Heave 2, in	-0.128	70	3.42	6.52	8.48	9.21
	2.512	0.30	-3.81	-6.30	-7.58	-8.73
Heave 3, in	0.265	73	3.52	6.57	8.07	9.69
	2.323	0.30	-2.96	-5.35	-6.58	-8.37
Heave 4, in	0.863	119	3.24	6.52	8.34	9.33
	2.591	0.30	-1.53	-4.65	-6.14	-8.89
Wave 0, in	-0.280	108	2.23	5.21	7.77	9.79
	2.140	0.30	-2.24	-4.75	-6.59	-8.15
Wave 2, in	-0.187	108	2.34	5.38	8.41	10.43
	2.174	0.30	-2.23	-4.66	-6.49	-7.83
Wave 3, in	-0.172	109	2.43	5.53	8.18	10.50
	2.214	0.30	-2.25	-4.77	-6.52	-7.67
Wave 4, in	-0.261	108	2.43	5.57	8.18	9.84
	2.251	0.30	-2.41	-4.90	-6.69	-7.33

TABLE 6.28

MODEL BREAKING WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 34.3
Waves 1.4 ft Significant Height

Run(s) : 15, Speed 0.829 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.029	37	5.08	8.87	11.05	12.12
	3.420	0.30	-3.95	-8.93	-15.06	-17.69
Heave 2, in	-0.175	35	3.51	6.42	8.00	8.04
	2.424	0.30	-3.56	-6.71	-8.87	-10.70
Heave 3, in	0.273	36	3.63	6.42	8.10	9.80
	2.118	0.30	-2.65	-4.97	-5.97	-6.36
Heave 4, in	2.225	41	4.69	7.48	8.48	8.60
	2.387	0.30	-1.32	-4.93	-6.83	-7.56
Wave 0, in	-0.328	36	2.68	5.61	8.05	8.38
	1.877	0.30	-2.79	-5.04	-6.43	-7.21
Wave 2, in	-0.239	37	2.80	5.86	8.09	8.28
	1.939	0.30	-2.71	-5.02	-6.54	-6.88
Wave 3, in	-0.247	35	3.41	6.47	8.44	9.40
	2.180	0.30	-3.19	-5.70	-7.27	-7.61
Wave 4, in	-0.309	37	3.19	6.39	8.24	8.55
	2.166	0.30	-3.16	-5.70	-6.89	-7.42

TABLE 6.29

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 10.4
Waves 0.50 ft Significant Height

Run(s) : 27, Speed 0.425 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.850	125	1.28	2.82	3.93	4.59
	1.869	0.30	-2.90	-4.56	-5.67	-6.71
Heave 2, in	-0.097	121	1.65	3.06	3.89	5.30
	1.482	0.30	-1.74	-2.92	-3.75	-4.70
Heave 3, in	0.478	105	2.15	3.31	4.05	4.87
	1.333	0.30	-1.04	-1.93	-2.44	-3.07
Heave 4, in	1.479	122	3.36	4.54	5.22	6.77
	1.555	0.30	-0.31	-1.56	-2.37	-3.75
Wave 0, in	-0.432	121	1.20	2.46	3.21	3.97
	1.341	0.30	-1.90	-2.92	-3.60	-4.76
Wave 2, in	-0.306	121	1.44	2.77	3.59	4.74
	1.380	0.30	-1.76	-2.82	-3.48	-4.28
Wave 3, in	-0.346	127	1.31	2.49	3.40	5.26
	1.374	0.30	-1.77	-2.90	-3.46	-4.15
Wave 4, in	-0.412	119	1.40	2.56	3.35	4.32
	1.400	0.30	-1.93	-3.05	-3.70	-4.98

TABLE 6.30

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 10.4
Waves 0.50 ft Significant Height

Run(s) : 28, Speed 0.872 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.572	65	1.78	3.30	4.41	4.76
	2.041	0.30	-2.85	-4.74	-6.07	-6.94
Heave 2, in	-0.154	59	1.48	2.83	3.88	4.47
	1.437	0.30	-1.75	-3.08	-3.94	-4.22
Heave 3, in	0.131	53	1.76	2.99	3.97	4.57
	1.301	0.30	-1.28	-2.27	-2.98	-3.36
Heave 4, in	2.365	68	3.68	4.83	5.61	6.29
	1.241	0.30	0.90	-0.15	-0.88	-1.99
Wave 0, in	-0.498	65	1.02	2.24	3.22	3.92
	1.316	0.30	-1.87	-2.96	-3.67	-4.27
Wave 2, in	-0.364	66	1.26	2.59	3.49	4.07
	1.375	0.30	-1.77	-2.79	-3.64	-4.17
Wave 3, in	-0.433	63	1.22	2.59	3.50	4.23
	1.411	0.30	-2.02	-3.00	-3.89	-4.33
Wave 4, in	-0.519	66	1.12	2.30	3.47	4.55
	1.415	0.30	-1.99	-3.16	-4.00	-4.55

TABLE 6.31

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 10.4
Waves 0.75 ft Significant Height

Run(s) : 29, Speed 0.396 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.281	115	1.77	4.34	6.44	12.71
	2.948	0.30	-4.19	-6.89	-9.21	-13.45
Heave 2, in	-0.103	100	2.62	4.59	6.16	11.00
	2.552	0.30	-2.73	-4.99	-7.68	-10.48
Heave 3, in	0.091	95	2.89	4.84	6.32	10.77
	2.157	0.30	-2.31	-3.85	-5.21	-6.42
Heave 4, in	1.501	124	3.96	5.92	7.42	10.45
	2.160	0.30	-0.83	-2.59	-3.96	-5.56
Wave 0, in	-0.441	104	2.23	4.12	5.76	11.69
	2.098	0.30	-2.72	-4.28	-5.24	-6.33
Wave 2, in	-0.312	109	2.24	4.20	5.93	12.33
	2.121	0.30	-2.55	-4.13	-5.28	-6.46
Wave 3, in	-0.349	112	2.36	4.31	5.74	10.58
	2.235	0.30	-2.58	-4.31	-5.65	-7.43
Wave 4, in	-0.432	109	2.29	4.16	5.80	10.37
	2.212	0.30	-2.77	-4.44	-5.76	-8.78

TABLE 6.32

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 10.4
Waves 0.75 ft Significant Height

Run(s) : 30, Speed 0.825 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.800	58	2.56	4.67	6.62	9.96
	3.241	0.30	-3.76	-7.07	-10.68	-19.84
Heave 2, in	-0.074	47	2.80	4.61	6.77	10.09
	2.419	0.30	-2.98	-5.05	-7.46	-12.02
Heave 3, in	0.091	43	2.77	4.40	6.31	10.01
	2.065	0.30	-2.57	-3.90	-5.48	-7.21
Heave 4, in	2.397	68	4.15	5.94	7.28	10.55
	1.801	0.30	0.56	-1.10	-2.33	-3.45
Wave 0, in	-0.498	52	2.16	3.90	5.62	9.32
	2.275	0.30	-2.86	-4.78	-6.18	-8.35
Wave 2, in	-0.372	52	2.28	4.01	5.88	9.68
	2.267	0.30	-2.82	-4.69	-6.19	-7.80
Wave 3, in	-0.452	53	2.13	4.17	5.97	9.77
	2.234	0.30	-2.77	-4.60	-6.20	-8.49
Wave 4, in	-0.510	48	2.62	4.46	6.68	11.53
	2.332	0.30	-2.95	-4.69	-6.79	-7.97

TABLE 6.33

MODEL BREAKING WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 10.4
Waves 1.4 ft Significant Height

Run(s) : 31, Speed 0.418 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.400	97	3.06	6.69	8.74	9.73
	3.547	0.30	-5.71	-8.88	-11.09	-12.62
Heave 2, in	-0.572	93	3.13	5.71	7.30	8.56
	2.766	0.30	-3.97	-6.23	-7.28	-7.74
Heave 3, in	-0.220	98	3.13	5.41	6.81	7.99
	2.519	0.30	-3.09	-5.30	-6.67	-7.46
Heave 4, in	1.120	104	4.71	7.09	8.05	8.52
	2.695	0.30	-2.25	-4.43	-5.48	-6.92
Wave 0, in	-0.478	91	3.34	5.85	7.72	9.66
	2.545	0.30	-3.62	-5.49	-6.86	-7.79
Wave 2, in	-0.361	92	3.48	6.14	8.37	9.94
	2.567	0.30	-3.50	-5.50	-7.06	-7.85
Wave 3, in	-0.415	94	3.50	6.14	7.74	8.82
	2.655	0.30	-3.58	-5.73	-7.34	-7.95
Wave 4, in	-0.495	95	3.39	6.24	8.10	10.25
	2.688	0.30	-3.68	-5.89	-7.28	-8.61

TABLE 6.34

MODEL BREAKING WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 10.4
Waves 1.4 ft Significant Height

Run(s) : 32, Speed 0.824 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.990	54	2.95	7.06	10.16	10.79
	3.823	0.30	-4.55	-9.18	-12.75	-15.70
Heave 2, in	-0.123	40	3.65	6.39	7.30	7.69
	2.686	0.30	-3.85	-7.08	-9.63	-13.12
Heave 3, in	0.274	44	3.41	6.56	7.60	8.41
	2.163	0.30	-2.18	-4.04	-5.05	-5.77
Heave 4, in	2.263	61	4.35	6.84	8.16	8.96
	2.092	0.30	-0.04	-2.58	-4.05	-4.44
Wave 0, in	-0.487	47	2.00	4.68	6.98	8.12
	2.048	0.30	-2.65	-5.03	-6.74	-7.25
Wave 2, in	-0.375	47	2.46	5.37	7.68	8.22
	2.113	0.30	-2.74	-5.17	-6.92	-7.58
Wave 3, in	-0.440	49	2.78	6.00	8.07	9.12
	2.447	0.30	-3.16	-5.77	-7.14	-7.34
Wave 4, in	-0.509	54	2.39	5.53	8.16	8.66
	2.361	0.30	-2.82	-5.49	-6.98	-7.59

TABLE 6.35

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 4.4
Waves 0.50 ft Significant Height

Run(s) : 41, Speed 0.436 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.397	123	0.88	2.67	3.86	5.86
	2.041	0.30	-3.57	-5.51	-6.70	-8.05
Heave 2, in	1.046	115	2.73	4.11	5.01	6.33
	1.522	0.30	-0.70	-1.94	-2.44	-3.30
Heave 3, in	0.372	101	2.04	3.23	3.99	5.29
	1.358	0.30	-1.10	-2.08	-2.57	-3.53
Heave 4, in	0.819	117	2.70	3.90	4.83	5.72
	1.558	0.30	-1.04	-2.31	-3.19	-4.43
Wave 0, in	-0.288	125	1.34	2.59	3.51	5.74
	1.362	0.30	-1.70	-2.80	-3.30	-3.64
Wave 2, in	-0.160	126	1.55	2.79	3.73	5.26
	1.402	0.30	-1.63	-2.77	-3.41	-4.28
Wave 3, in	-0.216	130	1.49	2.76	3.50	4.09
	1.420	0.30	-1.64	-2.79	-3.44	-4.71
Wave 4, in	-0.391	123	1.40	2.68	3.34	4.92
	1.467	0.30	-1.96	-3.15	-3.85	-4.94

TABLE 6.36

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 4.4
Waves 0.50 ft Significant Height

Run(s) : 42, Speed 0.856 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.518	65	0.76	2.24	3.50	4.07
	2.030	0.30	-3.65	-5.63	-7.54	-8.88
Heave 2, in	1.230	59	2.98	4.30	5.15	5.91
	1.510	0.30	-0.57	-1.84	-2.66	-3.33
Heave 3, in	0.773	55	2.38	3.57	4.49	4.83
	1.274	0.30	-0.60	-1.61	-2.45	-2.85
Heave 4, in	1.529	66	2.93	4.02	4.85	5.80
	1.229	0.30	0.09	-0.90	-1.66	-2.74
Wave 0, in	-0.314	67	1.20	2.30	3.36	4.60
	1.302	0.30	-1.68	-2.84	-3.44	-3.61
Wave 2, in	-0.192	66	1.41	2.69	3.67	5.07
	1.371	0.30	-1.65	-2.67	-3.48	-4.16
Wave 3, in	-0.272	69	1.45	2.75	3.72	4.49
	1.442	0.30	-1.71	-2.82	-3.80	-4.37
Wave 4, in	-0.436	67	1.28	2.48	3.35	3.77
	1.463	0.30	-1.95	-3.19	-4.00	-4.89

TABLE 6.37

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 4.4
Waves 0.75 ft Significant Height

Run(s) : 43, Speed 0.392 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.445	117	0.98	3.68	5.65	10.13
	3.430	0.30	-5.51	-8.88	-11.78	-15.63
Heave 2, in	0.966	105	3.52	5.54	6.90	11.60
	2.321	0.30	-1.68	-3.38	-4.84	-6.79
Heave 3, in	0.579	96	3.34	5.21	6.80	11.33
	2.186	0.30	-1.87	-3.41	-4.74	-5.96
Heave 4, in	0.872	121	3.38	5.56	6.90	10.86
	2.289	0.30	-1.66	-3.53	-5.21	-7.14
Wave 0, in	-0.302	109	2.31	4.27	6.05	12.50
	2.114	0.30	-2.49	-4.03	-5.03	-6.84
Wave 2, in	-0.180	110	2.40	4.35	5.91	12.53
	2.120	0.30	-2.47	-3.99	-5.05	-6.30
Wave 3, in	-0.218	110	2.49	4.44	5.96	11.82
	2.222	0.30	-2.51	-4.21	-5.51	-6.64
Wave 4, in	-0.374	111	2.38	4.23	5.60	9.94
	2.232	0.30	-2.62	-4.37	-5.84	-8.62

TABLE 6.38

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 4.4
Waves 0.75 ft Significant Height

Run(s) : 44, Speed 0.839 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.488	55	1.46	3.65	5.85	8.45
	3.698	0.30	-5.85	-10.10	-15.05	-20.29
Heave 2, in	1.132	47	4.02	5.92	7.89	10.19
	2.515	0.30	-1.83	-4.06	-7.04	-12.78
Heave 3, in	0.954	45	3.65	5.32	7.43	10.66
	2.128	0.30	-1.50	-2.98	-4.71	-6.99
Heave 4, in	1.698	56	3.90	5.62	7.15	10.72
	1.934	0.30	-0.49	-1.91	-3.07	-5.01
Wave 0, in	-0.363	47	2.32	4.08	6.17	8.89
	2.210	0.30	-2.81	-4.45	-5.91	-7.60
Wave 2, in	-0.241	48	2.42	4.18	6.49	9.40
	2.221	0.30	-2.80	-4.40	-5.87	-7.23
Wave 3, in	-0.324	50	2.46	4.51	6.42	10.36
	2.256	0.30	-2.61	-4.55	-6.01	-8.38
Wave 4, in	-0.485	51	2.39	4.33	6.20	11.46
	2.334	0.30	-2.90	-4.67	-6.36	-7.65

TABLE 6.39

MODEL BREAKING WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 4.4
Waves 1.4 ft Significant Height

Run(s) : 45, Speed 0.398 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-3.044	100	2.37	5.50	7.56	9.45
	4.350	0.30	-8.04	-12.34	-14.94	-16.39
Heave 2, in	0.995	100	4.84	7.20	8.71	9.66
	2.848	0.30	-2.63	-4.80	-6.11	-7.41
Heave 3, in	0.621	105	4.07	6.49	7.63	8.40
	2.606	0.30	-2.46	-4.37	-5.62	-5.97
Heave 4, in	0.422	108	4.31	6.61	7.34	8.07
	2.843	0.30	-3.20	-5.47	-6.90	-10.23
Wave 0, in	-0.248	100	3.55	6.04	7.87	9.69
	2.601	0.30	-3.43	-5.23	-6.39	-7.58
Wave 2, in	-0.127	99	3.76	6.35	8.41	10.01
	2.611	0.30	-3.31	-5.18	-6.57	-7.55
Wave 3, in	-0.172	101	3.78	6.53	8.15	9.82
	2.735	0.30	-3.46	-5.58	-7.01	-7.64
Wave 4, in	-0.328	100	3.70	6.52	8.35	10.32
	2.763	0.30	-3.68	-5.71	-7.11	-8.00

TABLE 6.40

MODEL BREAKING WAVE TEST RESULTS
Boom 1 x 24 ft B/W = 4.4
Waves 1.4 ft Significant Height

Run(s) : 46, Speed 0.841 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.831	49	2.21	6.44	9.26	9.87
	4.514	0.30	-7.33	-13.57	-19.36	-20.29
Heave 2, in	0.983	42	4.89	7.69	9.03	9.68
	2.867	0.30	-2.72	-6.15	-9.34	-11.47
Heave 3, in	1.138	51	3.86	6.83	8.35	9.28
	2.218	0.30	-1.34	-3.45	-4.62	-5.44
Heave 4, in	1.513	62	3.74	6.23	7.40	7.98
	2.148	0.30	-0.87	-3.58	-5.19	-6.25
Wave 0, in	-0.300	48	2.33	4.88	7.54	8.83
	1.970	0.30	-2.42	-4.56	-5.92	-6.76
Wave 2, in	-0.166	48	2.64	5.33	8.04	9.69
	2.081	0.30	-2.45	-4.66	-5.92	-6.72
Wave 3, in	-0.202	51	3.02	6.25	8.42	9.75
	2.486	0.30	-2.90	-5.31	-6.54	-7.40
Wave 4, in	-0.403	56	2.54	5.69	8.59	9.23
	2.355	0.30	-2.63	-5.18	-6.64	-8.08

TABLE 6.41

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 12 ft B/W = 9.9
Waves 0.50 ft Significant Height

Run(s) : 157, Speed 0.433 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.760	119	2.72	4.22	5.05	6.25
	1.637	0.30	-1.09	-2.53	-3.56	-4.74
Heave 2, in						
Heave 3, in						
Heave 4, in	2.190	137	3.79	5.17	6.26	7.95
	1.517	0.30	0.58	-0.79	-1.93	-4.12
Wave 0, in	-0.326	121	1.33	2.47	3.20	4.28
	1.351	0.30	-1.76	-2.97	-3.67	-4.56
Wave 2, in	-0.197	117	1.49	2.68	3.54	4.96
	1.379	0.30	-1.74	-2.90	-3.61	-4.37
Wave 3, in	-0.131	119	1.65	2.91	3.67	5.11
	1.435	0.30	-1.66	-2.88	-3.68	-4.81
Wave 4, in	-0.271	125	1.42	2.69	3.43	4.13
	1.396	0.30	-1.72	-2.92	-3.69	-4.43

TABLE 6.42

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 12 ft B/W = 9.9
Waves 0.50 ft Significant Height

Run(s) : 158, Speed 0.829 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.600	74	2.38	3.83	4.97	5.79
	1.716	0.30	-1.33	-2.74	-3.74	-4.70
Heave 2, in						
Heave 3, in						
Heave 4, in	3.147	76	4.75	5.94	6.94	7.52
	1.592	0.30	1.41	-0.34	-2.10	-3.49
Wave 0, in	-0.387	68	1.08	2.29	3.31	4.01
	1.290	0.30	-1.72	-2.78	-3.44	-3.87
Wave 2, in	-0.248	68	1.28	2.50	3.49	4.70
	1.325	0.30	-1.61	-2.69	-3.41	-3.66
Wave 3, in	-0.208	65	1.48	2.76	3.75	4.92
	1.388	0.30	-1.72	-2.84	-3.58	-3.79
Wave 4, in	-0.366	71	1.21	2.51	3.42	4.84
	1.406	0.30	-1.81	-2.96	-3.75	-4.25

TABLE 6.43

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 12 ft B/W = 9.9
Waves 0.75 ft Significant Height

Run(s) : 159, Speed 0.421 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.278	102	3.21	5.71	7.63	12.83
	2.689	0.30	-2.36	-4.40	-6.76	-10.13
Heave 2, in						
Heave 3, in						
Heave 4, in	1.965	138	4.22	6.47	8.16	11.16
	2.269	0.30	0.00	-2.30	-3.45	-5.01
Wave 0, in	-0.331	95	2.41	4.14	5.85	10.85
	2.061	0.30	-2.54	-4.00	-5.10	-6.47
Wave 2, in	-0.202	97	2.53	4.37	6.44	12.57
	2.092	0.30	-2.36	-3.84	-4.96	-6.43
Wave 3, in	-0.140	103	2.53	4.52	6.28	13.10
	2.167	0.30	-2.30	-3.87	-4.95	-6.51
Wave 4, in	-0.280	103	2.29	4.27	5.92	12.44
	2.108	0.30	-2.49	-4.04	-5.09	-5.88

TABLE 6.44

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 12 ft B/W = 9.9
Waves 0.75 ft Significant Height

Run(s) : 160, Speed 0.850 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.565	56	3.49	5.77	7.75	10.72
	2.620	0.30	-2.09	-4.66	-6.65	-8.34
Heave 2, in						
Heave 3, in						
Heave 4, in	2.770	64	5.05	7.05	8.35	8.87
	2.402	0.30	0.41	-1.96	-3.58	-4.93
Wave 0, in	-0.402	47	2.31	4.14	6.23	9.11
	2.186	0.30	-2.90	-4.51	-6.12	-7.05
Wave 2, in	-0.252	47	2.51	4.38	6.54	9.23
	2.251	0.30	-2.90	-4.53	-6.09	-7.00
Wave 3, in	-0.207	50	2.57	4.53	6.43	9.81
	2.337	0.30	-2.77	-4.59	-5.71	-7.23
Wave 4, in	-0.361	56	2.15	4.13	6.42	10.17
	2.255	0.30	-2.61	-4.62	-6.33	-8.55

TABLE 6.45

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1 x 12 ft B/W = 9.9
Waves 1.00 ft Significant Height

Run(s) : 161, Speed 0.417 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.305	94	3.80	6.84	8.93	11.89
	3.615	0.30	-3.67	-7.07	-9.57	-14.87
Heave 2, in						
Heave 3, in						
Heave 4, in	1.826	112	5.12	8.12	10.02	13.43
	3.294	0.30	-1.16	-4.18	-5.79	-8.30
Wave 0, in	-0.393	92	3.40	6.13	7.81	9.39
	3.064	0.30	-3.34	-5.91	-7.44	-9.07
Wave 2, in	-0.264	90	3.70	6.35	8.05	9.00
	3.105	0.30	-3.36	-5.88	-7.29	-8.94
Wave 3, in	-0.195	92	3.86	6.59	8.01	8.93
	3.239	0.30	-3.42	-6.05	-7.53	-9.83
Wave 4, in	-0.329	91	3.63	6.38	8.05	8.64
	3.143	0.30	-3.43	-5.81	-7.51	-10.02

TABLE 6.46

MODEL BREAKING WAVE TEST RESULTS
Boom 1 x 12 ft B/W = 9.9
Waves 1.4 ft Significant Height

Run(s) : 162, Speed 0.425 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.163	100	4.64	9.17	11.78	12.69
	3.610	0.30	-4.03	-6.28	-7.31	-8.90
Heave 2, in						
Heave 3, in						
Heave 4, in	2.212	135	5.43	8.53	10.18	12.93
	2.906	0.30	-0.19	-3.63	-5.54	-7.66
Wave 0, in	-0.343	98	3.36	5.93	7.88	9.50
	2.559	0.30	-3.35	-5.26	-6.48	-7.15
Wave 2, in	-0.217	98	3.60	6.40	8.51	10.34
	2.617	0.30	-3.24	-5.26	-6.48	-7.51
Wave 3, in	-0.149	101	3.73	6.63	8.39	10.27
	2.734	0.30	-3.14	-5.42	-6.62	-7.48
Wave 4, in	-0.280	102	3.54	6.38	8.18	10.14
	2.737	0.30	-3.44	-5.59	-6.75	-7.23

TABLE 6.47

MODEL BREAKING WAVE TEST RESULTS
Boom 1 x 12 ft B/W = 9.9
Waves 1.4 ft Significant Height

Run(s) : 163, Speed 0.847 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.429	45	5.25	9.80	12.96	14.04
	3.553	0.30	-3.78	-7.14	-9.75	-13.74
Heave 2, in						
Heave 3, in						
Heave 4, in	3.273	75	5.36	7.68	8.79	9.36
	2.153	0.30	1.53	-1.75	-4.08	-5.16
Wave 0, in	-0.364	46	2.43	5.23	7.44	8.02
	1.957	0.30	-2.47	-4.55	-5.73	-6.04
Wave 2, in	-0.234	47	2.59	5.47	7.69	8.59
	2.016	0.30	-2.41	-4.51	-5.71	-6.09
Wave 3, in	-0.179	47	3.01	6.09	8.32	8.90
	2.245	0.30	-2.60	-4.95	-6.13	-6.91
Wave 4, in	-0.296	49	3.16	6.27	8.76	9.44
	2.516	0.30	-3.04	-5.43	-6.68	-7.63

TABLE 6.48

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 33.6
Waves 0.50 ft Significant Height

Run(s) : 108, Speed 0.562 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.779	83	1.34	2.56	3.34	4.26
	1.849	0.30	-3.03	-4.76	-5.94	-7.01
Heave 2, in	2.167	86	3.76	4.92	5.69	6.68
	1.405	0.30	0.62	-0.68	-1.57	-2.60
Heave 3, in	2.835	79	4.49	5.75	6.67	7.95
	1.394	0.30	1.14	0.10	-0.62	-1.59
Heave 4, in	2.748	96	4.42	5.65	6.71	7.00
	1.577	0.30	1.04	-0.31	-0.85	-1.35
Wave 0, in	-0.237	92	1.34	2.35	2.92	4.44
	1.350	0.30	-1.75	-2.83	-3.47	-3.81
Wave 2, in	-0.182	92	1.49	2.59	3.21	4.20
	1.369	0.30	-1.70	-2.81	-3.50	-4.12
Wave 3, in	-0.211	90	1.62	2.89	3.81	4.43
	1.402	0.30	-1.75	-2.71	-3.48	-4.38
Wave 4, in	-0.365	89	1.50	2.75	3.56	4.34
	1.502	0.30	-2.13	-3.33	-4.03	-5.32

TABLE 6.49

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 33.6
Waves 0.50 ft Significant Height

Run(s) : 109, Speed 1.023 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.018	52	0.92	2.30	3.02	3.39
	1.794	0.30	-3.00	-4.59	-5.82	-6.67
Heave 2, in	1.694	49	3.27	4.43	5.35	5.87
	1.421	0.30	0.16	-1.05	-2.07	-2.53
Heave 3, in	2.633	47	4.02	5.04	5.72	5.97
	1.194	0.30	1.21	0.16	-0.53	-0.67
Heave 4, in	4.267	62	5.33	6.21	6.66	7.35
	1.306	0.30	2.96	1.48	0.67	-1.66
Wave 0, in	-0.282	54	1.08	2.18	2.91	3.33
	1.194	0.30	-1.58	-2.44	-3.21	-4.20
Wave 2, in	-0.228	57	1.22	2.29	3.18	3.54
	1.233	0.30	-1.59	-2.50	-3.30	-3.92
Wave 3, in	-0.261	56	1.31	2.37	3.09	4.11
	1.301	0.30	-1.65	-2.68	-3.58	-4.22
Wave 4, in	-0.385	56	1.18	2.38	3.56	4.61
	1.341	0.30	-1.85	-2.84	-3.65	-3.94

TABLE 6.50

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 33.6
Waves 0.75 ft Significant Height

Run(s) : 110, Speed 0.490 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.223	84	2.08	4.40	6.43	12.38
	2.933	0.30	-4.34	-7.03	-9.63	-13.13
Heave 2, in	1.872	81	4.68	6.82	8.49	11.73
	2.594	0.30	-0.69	-3.23	-5.62	-8.62
Heave 3, in	2.380	80	5.00	7.32	8.91	11.57
	2.485	0.30	-0.21	-2.50	-4.52	-7.25
Heave 4, in	2.135	114	4.52	6.88	9.13	13.38
	2.469	0.30	0.05	-2.07	-3.29	-4.34
Wave 0, in	-0.243	80	2.57	4.44	6.35	8.86
	2.253	0.30	-2.70	-4.55	-6.29	-8.98
Wave 2, in	-0.183	84	2.54	4.69	6.69	9.88
	2.325	0.30	-2.58	-4.46	-6.57	-9.03
Wave 3, in	-0.221	88	2.54	4.63	6.54	8.51
	2.370	0.30	-2.51	-4.50	-6.57	-9.25
Wave 4, in	-0.398	92	2.22	4.34	6.06	9.34
	2.367	0.30	-2.79	-4.72	-6.08	-8.91

TABLE 6.51

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 33.6
Waves 0.75 ft Significant Height

Run(s) : 111, Speed 1.049 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.650	43	2.70	5.05	7.13	7.49
	2.854	0.30	-3.53	-6.32	-8.28	-10.22
Heave 2, in	1.828	36	4.88	6.82	8.94	10.89
	2.513	0.30	-1.16	-3.05	-4.72	-5.64
Heave 3, in	2.530	36	5.21	6.83	8.74	11.43
	2.204	0.30	-0.21	-2.00	-4.52	-5.62
Heave 4, in	2.828	58	5.04	7.17	8.39	12.06
	2.612	0.30	0.66	-1.96	-3.69	-5.41
Wave 0, in	-0.278	37	2.69	4.67	6.40	8.99
	2.316	0.30	-3.00	-4.64	-6.29	-7.82
Wave 2, in	-0.229	38	2.66	4.63	6.44	9.53
	2.301	0.30	-2.85	-4.64	-6.26	-7.60
Wave 3, in	-0.290	40	2.61	4.64	6.25	10.56
	2.354	0.30	-2.62	-4.54	-6.54	-8.68
Wave 4, in	-0.454	40	2.62	4.68	6.80	11.35
	2.430	0.30	-2.97	-4.71	-6.60	-7.81

TABLE 6.52

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 33.6
Waves 1.00 ft Significant Height

Run(s) : 112, Speed 0.509 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.015	76	3.56	6.45	8.69	10.60
	3.869	0.30	-4.74	-8.24	-10.30	-11.70
Heave 2, in	2.047	71	6.13	8.80	10.46	11.43
	3.363	0.30	-1.43	-4.28	-5.79	-6.98
Heave 3, in	2.167	72	5.69	7.98	9.26	10.74
	3.026	0.30	-0.95	-3.81	-5.41	-6.71
Heave 4, in	1.674	100	4.97	7.66	10.03	14.07
	3.390	0.30	-1.28	-4.89	-6.81	-8.22
Wave 0, in	-0.264	74	3.85	6.71	8.80	11.19
	3.204	0.30	-3.49	-6.04	-7.05	-7.41
Wave 2, in	-0.218	75	3.72	6.59	8.47	9.72
	3.187	0.30	-3.41	-5.91	-7.07	-7.79
Wave 3, in	-0.241	77	3.60	6.61	8.67	13.26
	3.259	0.30	-3.34	-6.00	-7.37	-8.29
Wave 4, in	-0.413	76	3.46	6.51	8.99	13.46
	3.209	0.30	-3.63	-6.14	-7.64	-8.66

TABLE 6.53

MODEL BREAKING WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 33.6
Waves 1.4 ft Significant Height

Run(s) : 113, Speed 0.546 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.403	73	4.43	7.86	10.43	12.21
	3.565	0.30	-4.46	-7.84	-9.97	-12.77
Heave 2, in	1.504	68	5.29	8.14	9.84	12.03
	2.842	0.30	-1.80	-4.39	-6.22	-9.24
Heave 3, in	2.172	74	5.50	8.29	9.79	10.46
	2.694	0.30	-0.67	-3.45	-6.01	-10.58
Heave 4, in	1.096	87	4.68	7.74	9.25	9.81
	3.342	0.30	-2.01	-5.27	-7.85	-11.42
Wave 0, in	-0.255	70	3.49	6.19	7.82	9.67
	2.544	0.30	-3.38	-5.44	-7.02	-7.58
Wave 2, in	-0.213	70	3.56	6.43	8.22	10.44
	2.568	0.30	-3.31	-5.49	-7.09	-7.66
Wave 3, in	-0.234	72	3.65	6.54	8.12	9.60
	2.627	0.30	-3.32	-5.48	-6.71	-7.73
Wave 4, in	-0.408	74	3.37	6.52	8.77	9.74
	2.677	0.30	-3.54	-5.93	-6.90	-7.51

TABLE 6.54

MODEL BREAKING WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 33.6
Waves 1.4 ft Significant Height

Run(s) : 115, Speed 1.079 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.175	26	3.02	7.19	9.96	10.54
	2.767	0.30	-4.80	-8.46	-10.89	-11.46
Heave 2, in	1.675	24	4.95	8.15	9.73	9.96
	2.141	0.30	-1.54	-4.18	-7.28	-7.34
Heave 3, in	2.117	32	4.75	7.84	9.53	10.03
	1.858	0.30	0.32	-1.85	-3.65	-5.83
Heave 4, in	3.455	33	5.20	7.30	8.79	9.25
	2.152	0.30	1.04	-2.28	-4.89	-7.42
Wave 0, in	-0.273	26	2.34	5.03	7.34	7.34
	1.591	0.30	-2.30	-4.53	-6.24	-6.50
Wave 2, in	-0.196	24	3.14	5.69	7.30	7.38
	1.851	0.30	-2.82	-5.09	-6.45	-6.54
Wave 3, in	-0.221	25	3.55	6.72	8.98	9.90
	2.220	0.30	-3.32	-5.99	-7.38	-7.60
Wave 4, in	-0.400	27	2.85	5.50	7.30	7.45
	1.922	0.30	-2.96	-4.84	-6.70	-6.96

TABLE 6.55

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 10.3
Waves 0.50 ft Significant Height

Run(s) : 124, Speed 0.504 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.547	96	-0.63	0.59	1.30	2.00
	1.777	0.30	-4.51	-6.29	-7.55	-9.40
Heave 2, in	0.443	93	1.98	3.30	4.14	5.16
	1.645	0.30	-1.07	-2.73	-4.11	-4.98
Heave 3, in	-0.753	87	0.94	2.10	3.01	3.59
	1.592	0.30	-2.29	-3.95	-4.93	-6.44
Heave 4, in	1.741	103	3.57	4.79	5.57	6.38
	1.540	0.30	-0.09	-1.24	-1.93	-2.79
Wave 0, in	-0.202	100	1.40	2.53	3.29	5.02
	1.326	0.30	-1.67	-2.69	-3.24	-4.25
Wave 2, in	-0.101	105	1.51	2.72	3.54	4.92
	1.332	0.30	-1.51	-2.54	-3.22	-3.75
Wave 3, in	-0.120	102	1.61	2.87	3.62	4.34
	1.385	0.30	-1.66	-2.69	-3.43	-4.15
Wave 4, in	-0.232	102	1.62	2.99	3.86	4.53
	1.464	0.30	-1.86	-2.96	-3.75	-4.97

TABLE 6.56

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 10.3
Waves 0.50 ft Significant Height

Run(s) : 125, Speed 1.022 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.345	51	-0.37	0.92	1.93	2.62
	1.774	0.30	-4.48	-5.96	-7.16	-8.22
Heave 2, in	0.242	46	1.74	3.13	4.14	4.47
	1.398	0.30	-1.25	-2.42	-3.27	-3.63
Heave 3, in	-0.744	46	0.67	1.89	2.82	3.46
	1.305	0.30	-2.20	-3.34	-4.19	-5.00
Heave 4, in	3.485	65	4.59	5.24	5.85	6.95
	1.118	0.30	2.27	1.13	0.06	-2.39
Wave 0, in	-0.282	56	1.14	2.17	2.87	3.34
	1.214	0.30	-1.62	-2.54	-3.30	-3.77
Wave 2, in	-0.173	59	1.34	2.29	3.06	3.50
	1.254	0.30	-1.49	-2.57	-3.46	-3.80
Wave 3, in	-0.244	61	1.28	2.30	3.14	4.01
	1.325	0.30	-1.64	-2.76	-3.55	-4.36
Wave 4, in	-0.305	59	1.32	2.47	3.53	4.34
	1.381	0.30	-1.73	-2.90	-3.72	-4.07

TABLE 6.57

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 10.3
Waves 0.75 ft Significant Height

Run(s) : 126, Speed 0.503 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.884	82	0.26	2.56	4.76	8.86
	2.925	0.30	-6.08	-8.87	-11.13	-14.02
Heave 2, in	0.614	76	3.26	5.22	7.44	9.02
	2.327	0.30	-2.04	-3.99	-5.83	-8.65
Heave 3, in	-0.572	83	1.92	4.41	6.85	9.13
	2.448	0.30	-3.08	-5.11	-6.23	-8.36
Heave 4, in	1.564	109	3.82	6.12	8.51	11.36
	2.278	0.30	-0.53	-2.45	-3.78	-5.15
Wave 0, in	-0.247	79	2.57	4.54	6.42	8.25
	2.315	0.30	-2.64	-4.50	-6.41	-8.53
Wave 2, in	-0.157	80	2.70	4.74	6.30	8.69
	2.338	0.30	-2.66	-4.52	-6.15	-8.61
Wave 3, in	-0.205	87	2.53	4.69	6.76	9.66
	2.408	0.30	-2.55	-4.61	-6.24	-8.68
Wave 4, in	-0.317	88	2.55	4.82	7.27	10.42
	2.415	0.30	-2.72	-4.58	-6.09	-8.60

TABLE 6.58

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 10.3
Waves 0.75 ft Significant Height

Run(s) : 127, Speed 1.020 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.367	43	0.52	2.98	5.05	6.90
	2.780	0.30	-5.52	-8.11	-10.38	-11.82
Heave 2, in	0.844	38	3.70	5.60	7.55	9.56
	2.319	0.30	-1.76	-3.56	-6.03	-7.86
Heave 3, in	-0.120	42	2.52	4.37	5.92	8.91
	2.219	0.30	-2.34	-4.31	-6.33	-7.45
Heave 4, in	3.434	58	5.33	6.73	8.16	12.85
	2.068	0.30	1.55	-0.73	-2.41	-3.01
Wave 0, in	-0.314	39	2.50	4.23	6.18	8.90
	2.206	0.30	-2.66	-4.23	-5.73	-7.10
Wave 2, in	-0.223	40	2.43	4.35	6.01	9.82
	2.196	0.30	-2.52	-4.15	-5.79	-7.82
Wave 3, in	-0.318	39	2.77	4.58	6.93	10.27
	2.244	0.30	-2.69	-4.29	-6.58	-8.05
Wave 4, in	-0.349	45	2.32	4.33	6.51	11.30
	2.414	0.30	-2.84	-4.49	-6.13	-7.79

TABLE 6.59

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 10.3
Waves 1.00 ft Significant Height

Run(s) : 128, Speed 0.502 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-3.042 3.880	78 0.30	1.26 -6.86	4.25 -10.59	5.86 -12.42	7.37 -13.28
Heave 2, in	0.557 3.263	72 0.30	4.38 -2.81	6.87 -5.77	8.20 -7.21	9.11 -8.28
Heave 3, in	-0.327 3.130	73 0.30	3.35 -3.53	5.69 -6.34	6.89 -8.03	7.17 -9.73
Heave 4, in	1.672 3.104	103 0.30	4.62 -1.24	7.33 -4.05	9.75 -5.60	12.67 -8.43
Wave 0, in	-0.249 3.132	74 0.30	3.69 -3.43	6.39 -5.89	8.15 -7.26	10.09 -7.90
Wave 2, in	-0.144 3.142	75 0.30	3.67 -3.30	6.48 -5.74	8.53 -7.16	12.38 -7.86
Wave 3, in	-0.170 3.269	78 0.30	3.80 -3.34	6.60 -5.92	8.42 -7.25	12.62 -8.82
Wave 4, in	-0.285 3.204	77 0.30	3.60 -3.55	6.71 -5.93	9.00 -7.39	12.88 -7.95

TABLE 6.60

MODEL BREAKING WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 10.3
Waves 1.4 ft Significant Height

Run(s) : 129, Speed 0.516 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.792	76	1.34	5.33	7.76	10.49
	3.397	0.30	-6.74	-9.69	-11.82	-12.92
Heave 2, in	0.348	73	3.73	6.57	8.05	9.31
	2.578	0.30	-2.77	-4.95	-6.42	-8.38
Heave 3, in	-0.777	81	2.18	5.09	6.87	9.11
	2.454	0.30	-3.53	-5.63	-7.04	-8.09
Heave 4, in	1.353	94	4.78	7.48	8.84	9.30
	2.819	0.30	-1.74	-4.55	-6.02	-6.68
Wave 0, in	-0.217	72	3.26	5.69	7.85	8.72
	2.367	0.30	-3.16	-5.09	-6.34	-7.03
Wave 2, in	-0.132	74	3.25	5.91	7.79	8.42
	2.373	0.30	-2.99	-5.08	-6.52	-7.28
Wave 3, in	-0.174	76	3.34	6.27	8.11	9.47
	2.477	0.30	-3.07	-5.29	-6.59	-7.02
Wave 4, in	-0.256	80	3.46	6.78	9.15	11.15
	2.654	0.30	-3.20	-5.66	-6.98	-7.54

TABLE 6.61

MODEL BREAKING WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 10.3
Waves 1.4 ft Significant Height

Run(s) : 130, Speed 1.023 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.733	36	1.04	5.67	8.65	9.42
	3.161	0.30	-6.23	-10.06	-11.48	-11.64
Heave 2, in	-0.061	28	3.43	6.97	8.21	8.67
	2.434	0.30	-3.19	-5.50	-7.91	-7.92
Heave 3, in	-0.673	37	2.06	5.67	7.14	7.64
	2.245	0.30	-2.96	-5.22	-6.64	-7.22
Heave 4, in	3.102	53	4.84	6.84	8.40	8.92
	1.948	0.30	1.29	-1.59	-4.29	-6.28
Wave 0, in	-0.280	36	2.00	4.54	6.92	7.87
	1.655	0.30	-2.06	-4.06	-5.88	-6.58
Wave 2, in	-0.169	36	2.61	5.58	8.17	8.89
	2.001	0.30	-2.37	-4.74	-6.66	-7.09
Wave 3, in	-0.211	39	2.87	6.48	9.46	9.96
	2.495	0.30	-2.74	-5.74	-7.52	-8.73
Wave 4, in	-0.341	44	2.17	5.17	7.73	8.32
	2.080	0.30	-2.38	-4.87	-6.55	-7.14

TABLE 6.62

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 5.0
Waves 0.50 ft Significant Height

Run(s) : 140, Speed 0.527 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.451	93	-0.47	0.86	1.99	2.72
	1.820	0.30	-4.50	-6.39	-7.56	-8.87
Heave 2, in	1.165	87	2.71	3.90	4.58	5.26
	1.378	0.30	-0.44	-1.65	-2.56	-3.58
Heave 3, in	-0.188	89	1.49	3.14	3.86	5.39
	1.656	0.30	-1.87	-3.34	-4.04	-4.72
Heave 4, in	0.908	93	2.86	4.10	4.92	5.98
	1.620	0.30	-1.10	-2.19	-3.07	-4.57
Wave 0, in	-0.177	91	1.48	2.50	3.19	5.13
	1.335	0.30	-1.75	-2.77	-3.35	-4.22
Wave 2, in	-0.072	94	1.60	2.70	3.49	4.95
	1.334	0.30	-1.53	-2.62	-3.16	-4.00
Wave 3, in	-0.138	97	1.57	2.85	3.72	4.37
	1.373	0.30	-1.65	-2.70	-3.46	-4.13
Wave 4, in	-0.289	98	1.57	2.80	3.76	4.42
	1.483	0.30	-1.93	-3.20	-4.01	-5.68

TABLE 6.63

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 5.0
Waves 0.50 ft Significant Height

Run(s) : 141, Speed 1.039 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.300	50	-0.33	1.10	2.07	2.46
	1.783	0.30	-4.33	-5.97	-7.21	-8.70
Heave 2, in	1.210	47	2.74	3.82	4.48	4.86
	1.327	0.30	-0.21	-1.35	-2.47	-3.84
Heave 3, in	-0.391	45	1.12	2.22	2.99	3.61
	1.365	0.30	-1.93	-3.23	-4.34	-5.82
Heave 4, in	2.486	59	3.59	4.53	5.32	6.37
	1.117	0.30	1.14	0.29	-0.75	-1.86
Wave 0, in	-0.217	54	1.15	2.14	2.90	3.59
	1.173	0.30	-1.52	-2.38	-3.18	-3.62
Wave 2, in	-0.094	56	1.38	2.32	2.96	3.63
	1.211	0.30	-1.43	-2.40	-3.26	-3.59
Wave 3, in	-0.206	55	1.41	2.48	3.10	3.59
	1.321	0.30	-1.70	-2.74	-3.49	-4.25
Wave 4, in	-0.288	57	1.29	2.49	3.56	4.01
	1.379	0.30	-1.82	-2.88	-3.76	-4.10

TABLE 6.64

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 5.0
Waves 0.75 ft Significant Height

Run(s) : 142, Speed 0.501 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.411	89	0.69	3.31	5.87	11.55
	3.036	0.30	-5.49	-8.55	-11.31	-13.98
Heave 2, in	0.973	77	3.64	5.71	7.94	10.05
	2.354	0.30	-1.60	-3.65	-5.76	-8.26
Heave 3, in	-0.905	81	1.75	4.11	6.35	8.82
	2.477	0.30	-3.49	-5.56	-6.98	-9.08
Heave 4, in	0.807	96	3.17	5.79	7.91	10.08
	2.410	0.30	-1.71	-3.52	-4.96	-9.52
Wave 0, in	-0.230	82	2.48	4.38	5.94	8.22
	2.257	0.30	-2.55	-4.40	-6.29	-8.09
Wave 2, in	-0.104	80	2.73	4.81	6.32	8.02
	2.326	0.30	-2.56	-4.48	-6.34	-8.20
Wave 3, in	-0.168	89	2.63	4.79	6.59	8.71
	2.415	0.30	-2.51	-4.58	-6.36	-8.84
Wave 4, in	-0.324	87	2.60	4.71	6.82	9.84
	2.415	0.30	-2.74	-4.60	-5.92	-8.41

TABLE 6.65

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 5.0
Waves 0.75 ft Significant Height

Run(s) : 143, Speed 1.028 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.378	44	0.55	3.20	5.64	7.82
	2.910	0.30	-5.57	-8.49	-10.72	-12.66
Heave 2, in	1.142	36	4.03	6.07	8.01	9.67
	2.350	0.30	-1.64	-3.27	-5.82	-8.06
Heave 3, in	-0.454	37	2.30	4.10	6.16	8.34
	2.203	0.30	-2.97	-4.65	-6.50	-7.39
Heave 4, in	2.655	53	4.46	6.12	7.58	11.99
	1.956	0.30	0.66	-1.10	-2.31	-5.15
Wave 0, in	-0.252	38	2.56	4.51	6.14	9.07
	2.211	0.30	-2.71	-4.32	-5.64	-6.73
Wave 2, in	-0.141	41	2.48	4.52	6.23	10.33
	2.189	0.30	-2.34	-4.20	-5.77	-7.57
Wave 3, in	-0.270	39	2.60	4.51	6.94	10.77
	2.268	0.30	-2.79	-4.37	-6.72	-7.97
Wave 4, in	-0.347	42	2.55	4.57	6.56	12.09
	2.415	0.30	-2.87	-4.50	-6.28	-7.63

TABLE 6.66

MODEL IRREGULAR WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 5.0
Waves 1.00 ft Significant Height

Run(s) : 144, Speed 0.538 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-3.157	77	0.93	3.90	5.20	6.39
	3.932	0.30	-6.84	-10.78	-13.56	-14.75
Heave 2, in	0.752	71	4.14	6.48	7.52	7.84
	3.075	0.30	-2.32	-5.13	-7.18	-9.24
Heave 3, in	-0.780	70	2.66	5.31	6.77	7.63
	3.097	0.30	-3.98	-6.61	-8.20	-9.18
Heave 4, in	1.225	85	4.53	7.31	9.41	10.46
	3.091	0.30	-1.95	-4.37	-5.99	-8.95
Wave 0, in	-0.177	73	3.26	5.94	7.22	8.35
	3.020	0.30	-3.07	-5.50	-6.81	-7.85
Wave 2, in	-0.072	75	3.35	5.95	7.75	9.69
	3.001	0.30	-3.00	-5.53	-7.07	-7.91
Wave 3, in	-0.161	72	3.70	6.29	8.26	10.08
	3.103	0.30	-3.17	-5.81	-7.11	-7.76
Wave 4, in	-0.348	74	3.46	6.19	7.94	8.71
	3.167	0.30	-3.56	-6.02	-7.54	-7.80

TABLE 6.67

MODEL BREAKING WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 5.0
Waves 1.4 ft Significant Height

Run(s) : 145, Speed 0.538 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.912	71	2.56	6.31	7.92	9.67
	3.431	0.30	-6.17	-9.05	-11.24	-12.53
Heave 2, in	1.268	73	4.60	6.88	8.25	9.50
	2.528	0.30	-1.80	-4.11	-5.51	-6.07
Heave 3, in	0.219	75	3.87	6.82	8.25	9.07
	2.800	0.30	-2.68	-4.80	-6.40	-7.13
Heave 4, in	0.863	85	4.48	7.32	8.44	8.66
	2.870	0.30	-2.63	-5.17	-6.46	-7.06
Wave 0, in	-0.195	71	3.24	5.61	7.31	9.32
	2.351	0.30	-3.12	-4.97	-6.15	-6.95
Wave 2, in	-0.086	73	3.27	5.79	7.43	8.63
	2.359	0.30	-2.90	-4.87	-6.44	-7.15
Wave 3, in	-0.161	75	3.40	6.23	7.79	10.06
	2.524	0.30	-3.11	-5.30	-6.79	-7.22
Wave 4, in	-0.292	79	3.27	6.57	8.69	10.10
	2.676	0.30	-3.27	-5.71	-7.14	-7.95

TABLE 6.68

MODEL BREAKING WAVE TEST RESULTS
Boom 1.5 x 24 ft B/W = 5.0
Waves 1.4 ft Significant Height

Run(s) : 146, Speed 1.029 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.481	32	1.83	6.25	8.94	9.61
	3.152	0.30	-6.41	-10.16	-12.00	-12.90
Heave 2, in	1.090	30	4.70	7.39	8.28	8.60
	2.244	0.30	-1.70	-3.94	-5.93	-6.23
Heave 3, in	-0.299	35	3.04	6.75	8.18	8.60
	2.474	0.30	-2.74	-4.68	-6.04	-6.57
Heave 4, in	2.399	51	4.02	6.31	7.82	8.69
	1.795	0.30	0.64	-1.71	-3.93	-5.16
Wave 0, in	-0.259	38	1.74	4.07	6.12	6.36
	1.564	0.30	-1.98	-3.89	-5.52	-5.63
Wave 2, in	-0.115	33	3.04	5.84	8.31	8.55
	2.069	0.30	-2.72	-4.87	-6.62	-6.89
Wave 3, in	-0.221	37	3.18	6.89	9.53	10.25
	2.517	0.30	-3.04	-5.81	-7.73	-8.70
Wave 4, in	-0.392	44	2.04	4.88	7.49	7.69
	1.993	0.30	-2.25	-4.54	-6.57	-7.11

TABLE 7.1

ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration: Height (ft)	Boom Configuration: Length (ft)	Boom Configuration: Gap/Length	Boom Configuration: B/W	Wave Configuration: Type	Wave Configuration: Height (ft)	Wave Configuration: Length (ft)	Wave Configuration: Period Max En (sec)	Speed (knot)	Drag (lb)
50	1/8	4	192	1/3	16.2	Regular	4	48	3.06	0	527
51										0.5	641
52										1.0	1314
53										2.0	4002
54						Regular	8	96	4.35	0.5	946
55										1.0	1135
56						Regular	12	144	5.46	0.5	1033
57										0.9	1802
58						Irregular	4	---	5.54	0.5	125
59										1.0	407
61						Irregular	6	---	6.78	0.5	162
62										1.0	1068
60						Irregular	8	---	7.83	0.5	413
63						Breaking	11.3	---	4.24	0.5	604
64										0.9	1227
80	1/8	4	192	1/3	12.5	Regular	4	48	3.06	0	950
81										0.5	756
82										1.0	1329
83										1.9	3384
84						Regular	8	96	4.35	0.5	780
85										1.0	1482
86						Regular	12	144	5.46	0.5	1254
87										0.9	2134
88						Irregular	4	---	5.54	0.5	82
89										1.0	375
90						Irregular	6	---	6.78	0.5	357
91										1.0	710
92						Irregular	8	---	7.83	0.5	395
93						Breaking	11.3	---	4.24	0.5	923
94										1.0	1519

TABLE 7.2

ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration				Wave Configuration				Speed	Drag
		Height ft	Length ft	Gap/Length	B/W	Type	Height ft	Length ft	Period Max En sec	knot	lb
65	1/8	4	192	1/3	9.6	Regular	4	48	3.06	0	356
66										0.5	938
67										1.0	1436
68										2.0	3536
69						Regular	8	96	4.35	0.5	937
70										1.0	1524
71						Regular	12	144	5.46	0.5	1145
72										1.0	2163
73						Irregular	4	---	5.54	0.5	139
74										1.0	622
75						Irregular	6	---	6.78	0.5	395
76										1.0	763
77						Irregular	8	---	7.83	0.5	288
78						Breaking	11.3	---	4.2	0.5	675
79										1.0	1379
1	1/4	4	96	1/3	34.3	Regular	2	24	2.17	0	112
2										0.5	227
3										1.0	524
4										2.0	1920
6						Regular	4	48	3.08	0.5	205
5										0.9	488
7										1.0	509
8						Regular	6	72	3.86	0.5	241
9										1.0	619
10						Irregular	2	---	3.91	0.5	94
11										1.0	447
13						Irregular	3	---	4.79	0.5	107
14										1.0	435
12						Irregular	4	---	5.54	0.5	126
16						Breaking	5.6	---	3.0	0.5	176
15										1.0	490

TABLE 7.3

ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration				Wave Configuration				Speed	Drag
		Height ft	Length ft	Gap / Length	B/W	Type	Height ft	Length ft	Period Max En sec	knot	lb
17	1/4	4	96	1/3	10.4	Regular	2	24	2.17	0	80
18										0.5	236
19										0.9	659
20										2.0	2345
21						Regular	4	48	3.08	0.5	327
22										1.0	710
23						Regular	6	72	3.86	0.5	358
26										0.5	372
24										1.0	921
25										1.0	927
27						Irregular	2	---	3.91	0.5	93
28										1.0	492
29						Irregular	3	---	4.79	0.5	147
30										1.0	518
31						Breaking	5.6	---	3.0	0.5	317
32										1.0	691
33	1/4	4	96	1/3	4.4	Regular	2	24	2.17	0	108
34										0.5	369
35										0.9	812
36										2.0	2807
37						Regular	4	48	3.08	0.5	437
38										1.0	1011
39						Regular	6	72	3.86	0.5	503
40										1.0	1208
41						Irregular	2	---	3.91	0.5	170
42										1.0	664
43						Irregular	3	---	4.79	0.5	182
44										1.0	718
45						Breaking	5.6	---	3.0	0.5	283
46										1.0	878

TABLE 7.4

ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration Height ft	Boom Configuration Length ft	Boom Configuration Gap/Length	Boom Configuration B/W	Wave Configuration Type	Wave Configuration Height ft	Wave Configuration Length ft	Wave Configuration Period Max En sec	Speed knot	Drag lb
164	1/4	4	48	2/3	9.9	Regular	2	24	2.17	0	89
150										0.6	335
151										0.9	692
152										1.9	1926
153						Regular	4	48	3.08	0.6	419
154										1.0	794
155						Regular	6	72	3.86	0.5	415
156										1.0	1064
157						Irregular	2	---	3.91	0.5	220
158										1.0	620
159						Irregular	3	---	4.79	0.5	250
160										1.0	718
161						Irregular	4	---	5.54	0.5	292
162						Breaking	5.6	---	3.0	0.5	399
163										1.0	836
99	3/8	4	64	1/3	33.6	Regular	1.3	16	1.77	0	28
100										0.5	136
101										1.0	436
102										2.2	2198
104						Regular	2.7	32	2.51	0.5	145
105										1.0	510
106						Regular	4	48	3.15	0.6	206
107										1.0	467
108						Irregular	1.3	---	3.20	0.5	100
109										1.0	346
110						Irregular	2	---	3.91	0.5	85
111										1.0	369
112						Irregular	2.7	---	4.52	0.5	112
113						Breaking	3.7	---	2.4	0.5	156
115										1.0	422

TABLE 7.5

ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration Height	Boom Configuration Length	Boom Configuration Gap/Length	Boom Configuration B/W	Wave Configuration Type	Wave Configuration Height	Wave Configuration Length	Wave Configuration Period Max En	Speed	Drag
		ft	ft				ft	ft	sec	knot	lb
116	3/8	4	64	1/3	10.3	Regular	1.3	16	1.77	0	37
117										0.5	181
118										1.0	574
119										1.9	1847
120						Regular	2.7	32	2.51	0.5	223
121										1.0	623
122						Regular	4	48	3.15	0.5	292
123										1.0	675
124						Irregular	1.3	---	3.20	0.5	110
125										1.0	429
126						Irregular	2	---	3.91	0.5	140
127										1.0	458
128						Irregular	2.7	---	4.52	0.5	147
129						Breaking	3.7	---	2.4	0.5	199
130										1.0	493
131	3/8	4	64	1/3	5.0	Regular	1.3	16	1.77	0	32
132										0.5	226
133										1.0	661
134										1.9	2016
135						Regular	2.7	32	2.51	0.5	313
136										1.0	716
137						Regular	4	48	3.15	0.5	417
139										1.0	908
140						Irregular	1.3	---	3.20	0.5	159
141										1.0	533
142						Irregular	2	---	3.91	0.5	174
143										1.0	560
144						Irregular	2.7	---	4.52	0.5	220
145						Breaking	3.7	---	2.4	0.5	243
146										1.0	627

TABLE 8

CALM WATER DRAG RESULTS
Predicted Full Scale Values

Scale	Boom Configuration Height ft	Length ft	Gap / Length	B/W	Speed knot	Drag lb
1/8	4	192	1/3	16.2	1.0	154
					2.2	2107
					3.4	Sinks
1/4	4	96	1/3	34.3	2.0	1624
					2.9	3808
1/4	4	48	2/3	9.9	0.4	103
					0.9	450
					1.7	1644
3/8	4	64	1/3	33.6	1.0	330
					1.8	1248
					2.0	1481

TABLE 9

COMPARISONS OF DRAG AND CENTERLINE HEAVE RESPONSE
All Booms Scaled to 4 ft Height in Regular 12:1 L/H Waves

Run	Scale	Boom Configuration Length ft	Gap/Length	B/W	Wave Height ft	Test Results Speed knot	Drag lb	RMS Heave 0 / RMS Wave 0
			Effects of Scale and Speed at B/W = 10					
66	1/8	192	1/3	9.6	4	0.5	938	1.45
21	1/4	96	1/3	10.4	4	0.5	327	1.41
122	3/8	64	1/3	10.3	4	0.5	292	1.27
67	1/8	192	1/3	9.6	4	1.0	1436	1.45
22	1/4	96	1/3	10.4	4	1.0	710	1.47
123	3/8	64	1/3	10.3	4	1.0	675	1.49
			Effects of B/W Ratio and Speed					
6	1/4	96	1/3	34.3	4	0.5	205	1.38
21	1/4	96	1/3	10.4	4	0.5	327	1.41
37	1/4	96	1/3	4.4	4	0.5	437	1.82
7	1/4	96	1/3	34.3	4	1.0	509	1.39
22	1/4	96	1/3	10.4	4	1.0	710	1.47
38	1/4	96	1/3	4.4	4	1.0	1011	1.65
			Effects of Wave Height and Speed at B/W = 10					
66	1/8	192	1/3	9.6	4	0.5	938	1.45
69	1/8	192	1/3	9.6	8	0.5	937	1.36
71	1/8	192	1/3	9.6	12	0.5	1145	1.22
67	1/8	192	1/3	9.6	4	1.0	1436	1.45
70	1/8	192	1/3	9.6	8	1.0	1524	1.32
72	1/8	192	1/3	9.6	12	1.0	2163	1.26
			Effects of Gap/Length Ratio and Speed at B/W = 10					
21	1/4	96	1/3	10.4	4	0.5	327	1.41
153	1/4	48	2/3	9.9	4	0.6	419	1.36
22	1/4	96	1/3	10.4	4	1.0	710	1.47
154	1/4	48	2/3	9.9	4	1.0	794	1.39

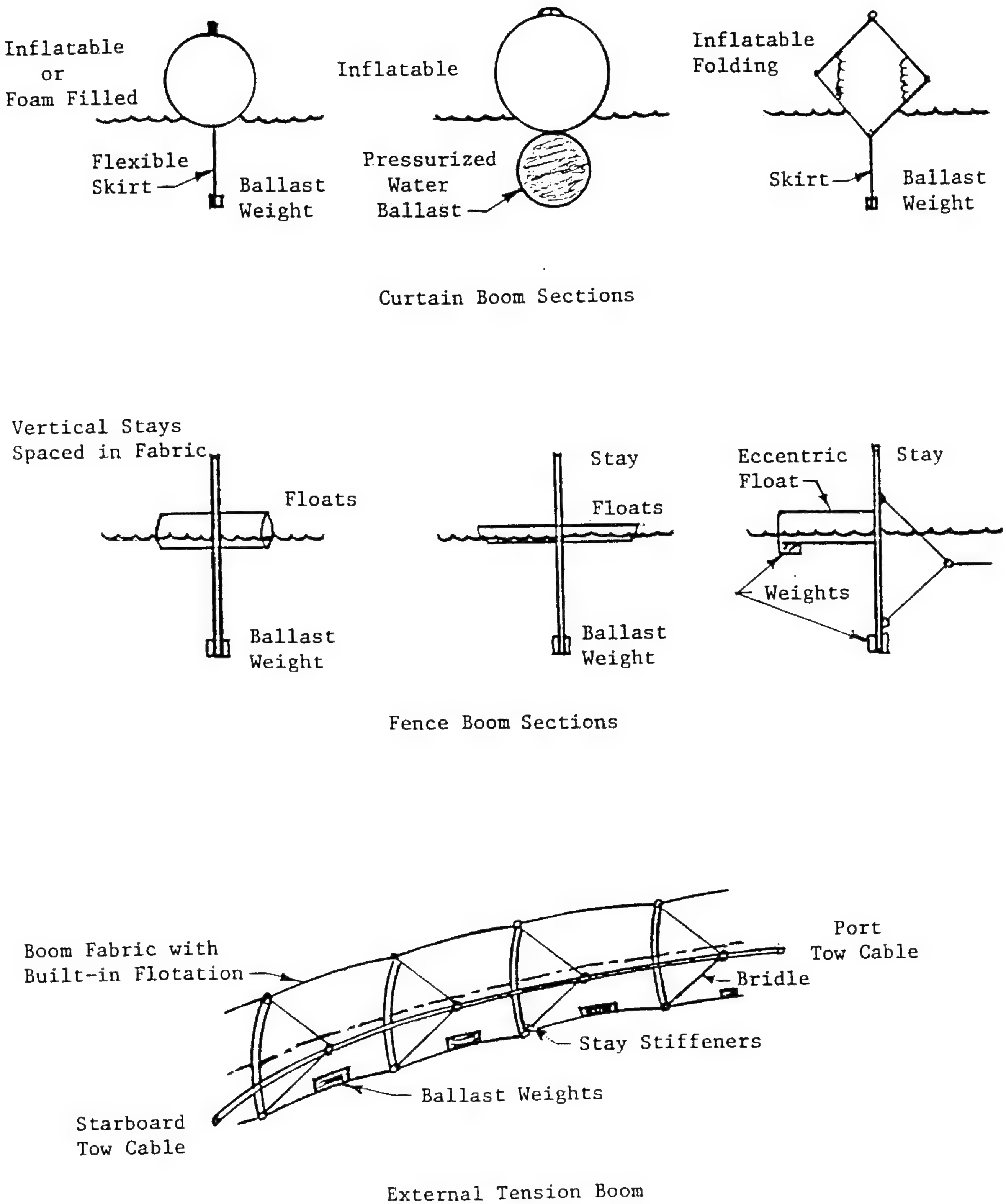
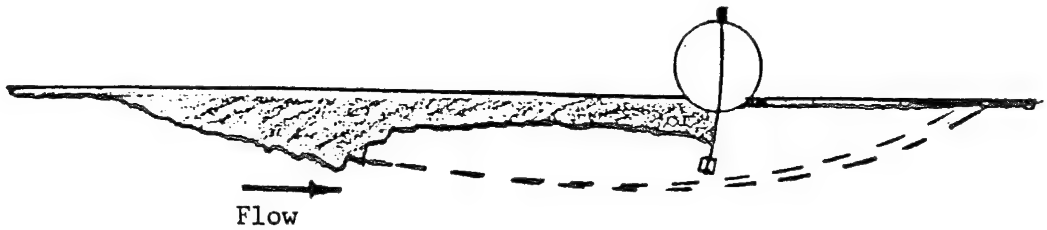
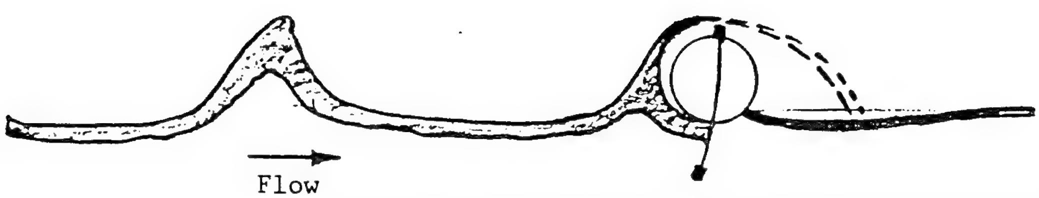


FIGURE 1A TYPICAL TYPES OF BOOMS

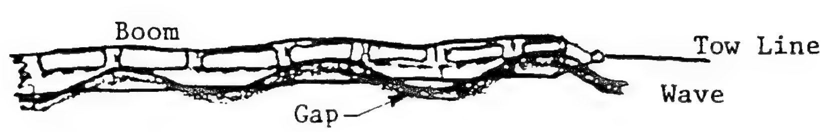


Entrainment Due to Excess Velocity (V > 1 knot)

Drainage Due to Excess Oil and Velocity



Splashover in Breaking Waves Due to Freeboard



Broaching in Waves - Tension Too High, Heave Not Stiff Enough

FIGURE 2A PRINCIPAL BOOM FAILURE MODES

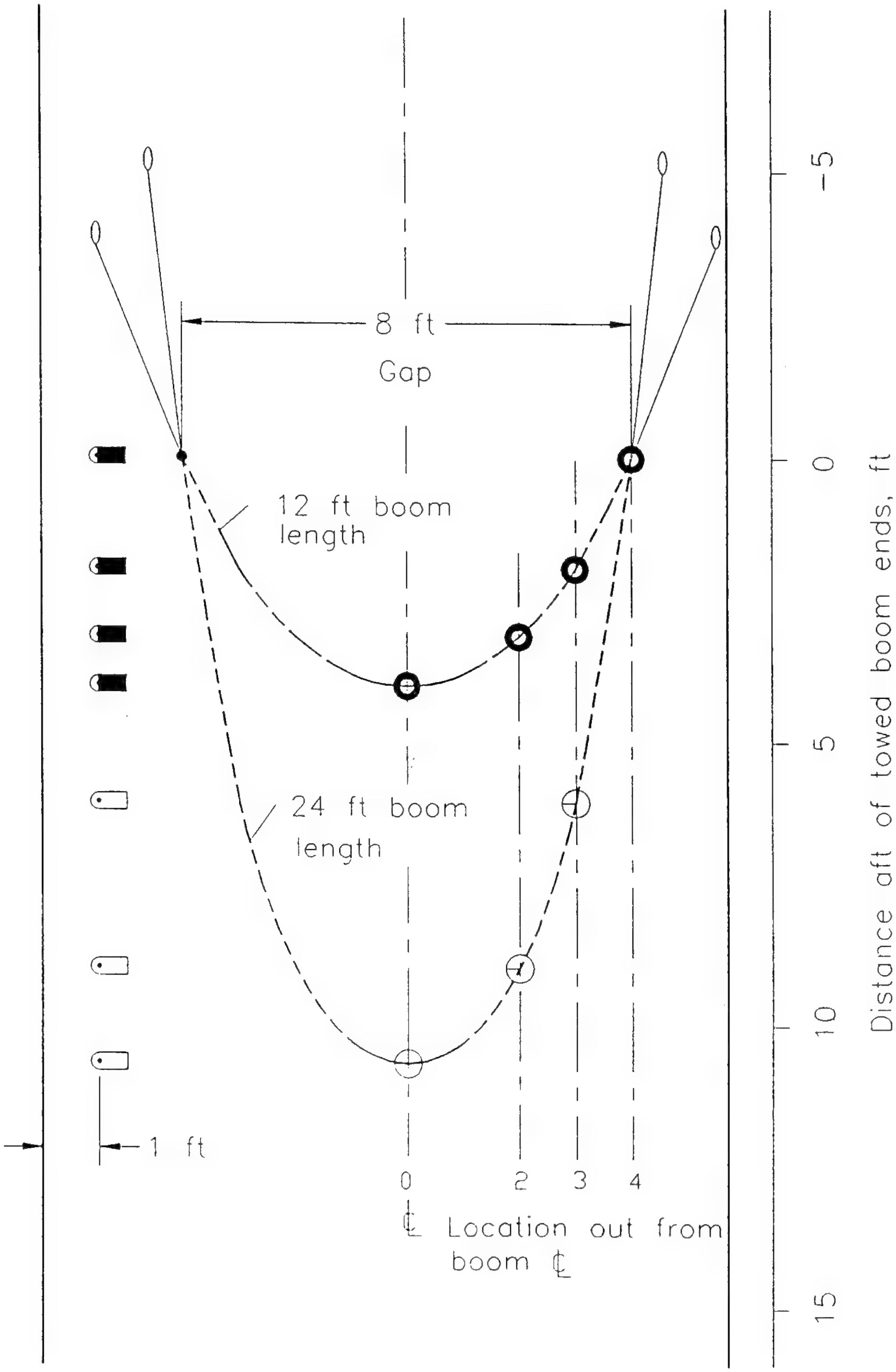


FIGURE 1 CATENARY TOW MODEL DIMENSIONS

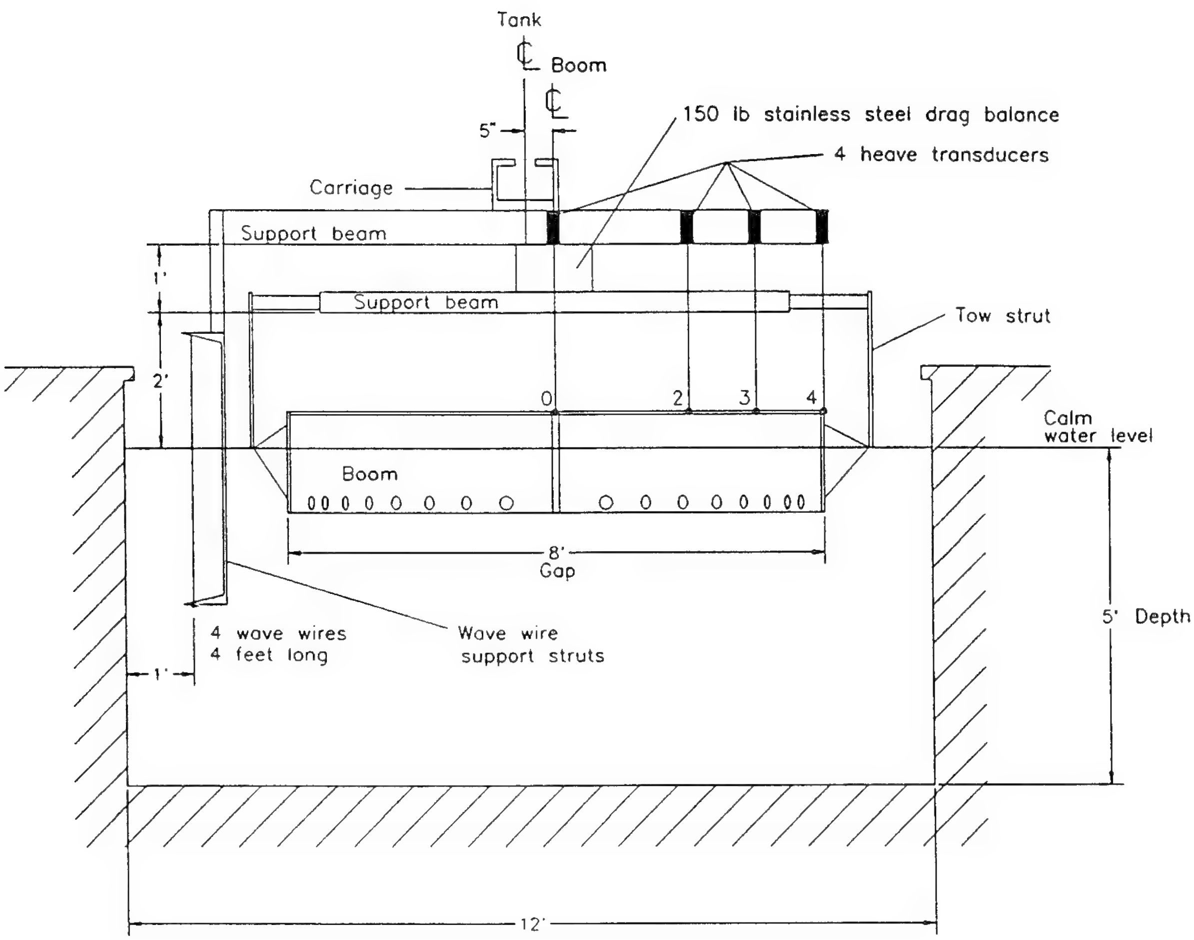
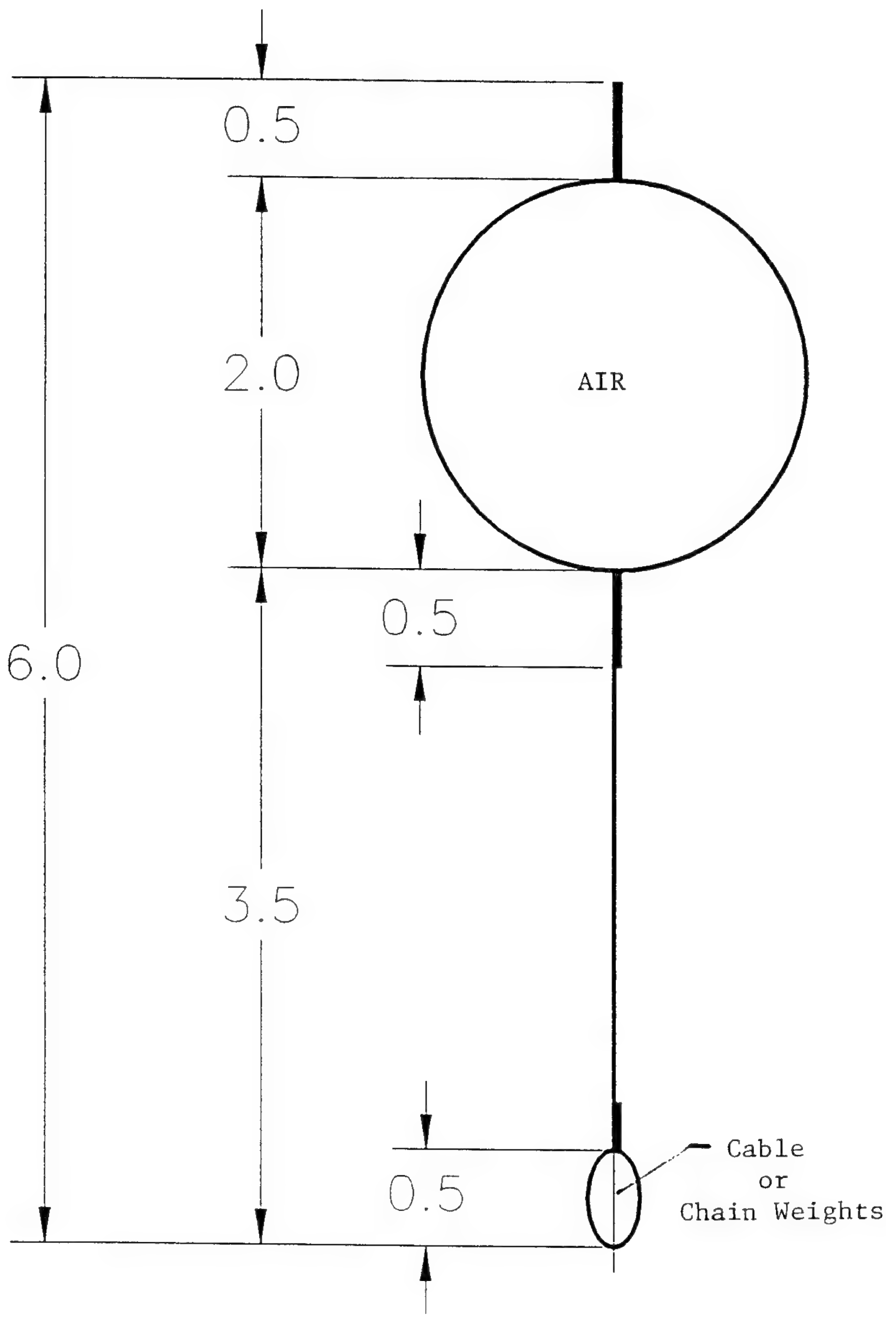
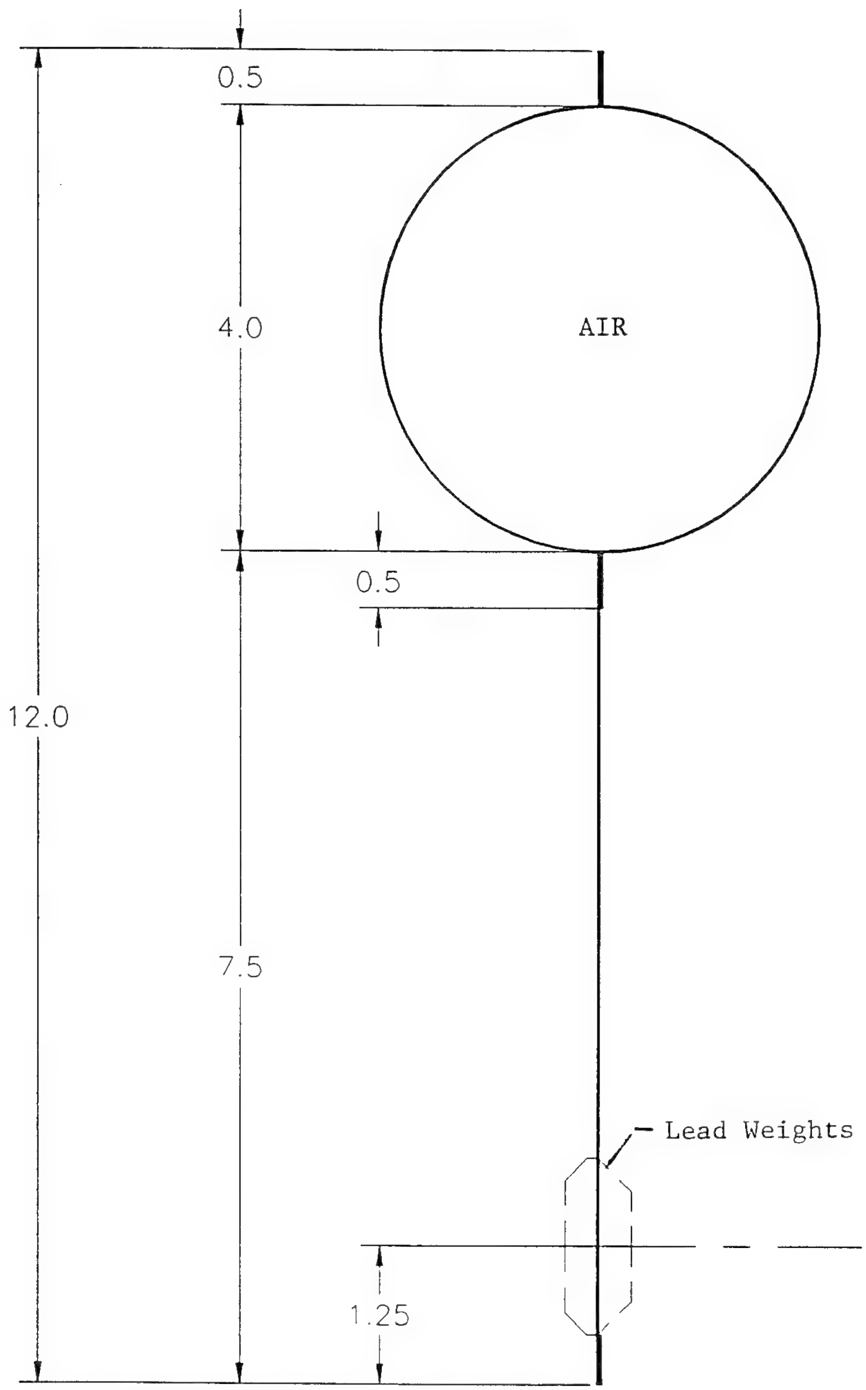


FIGURE 2 SECTIONAL VIEW OF MODEL TOW SETUP



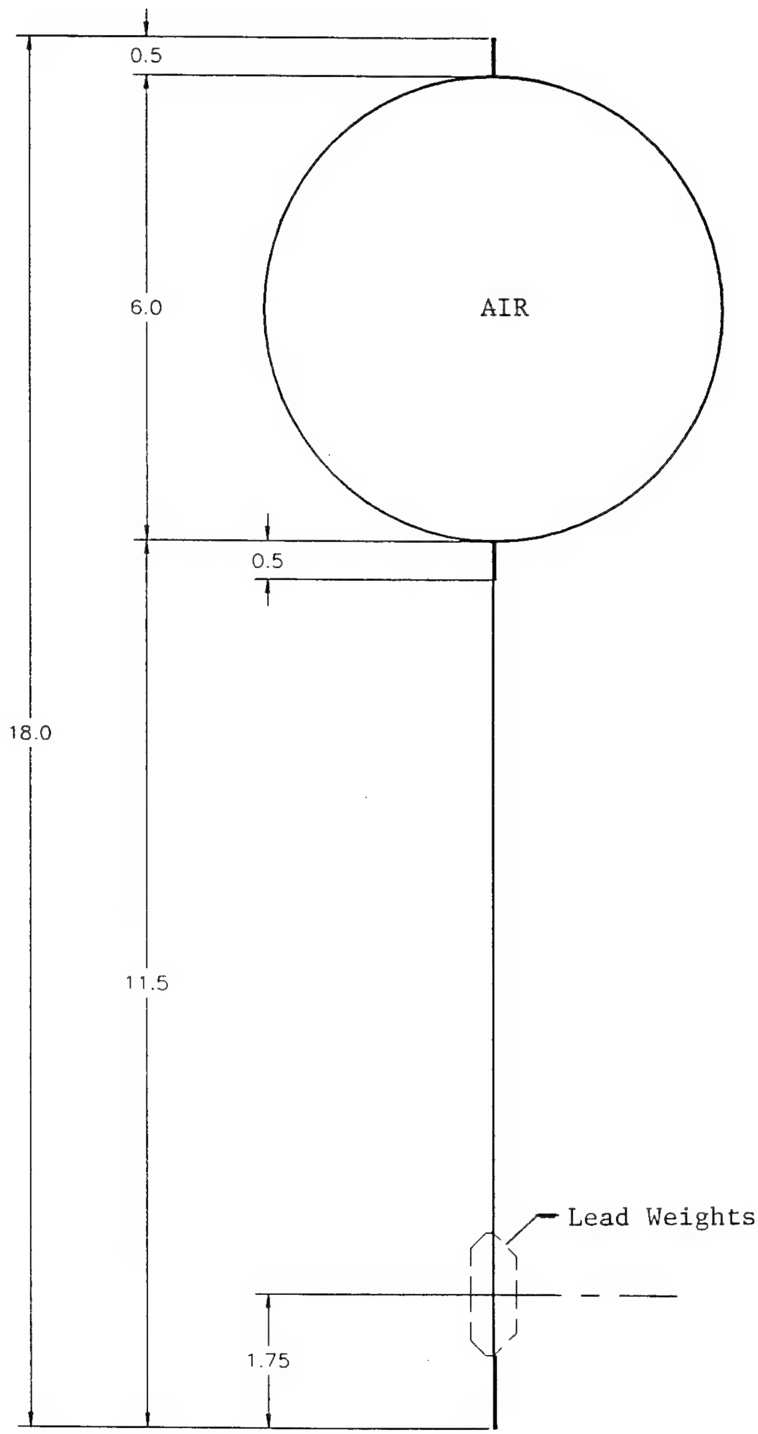
Dimensions are inches model scale

FIGURE 3 SECTION OF 0.5 FT MODEL BOOM



Dimensions are inches model scale

FIGURE 4 SECTION OF 1.0 FT MODEL BOOM



Dimensions are inches model scale

FIGURE 5 SECTION OF 1.5 FT MODEL BOOM

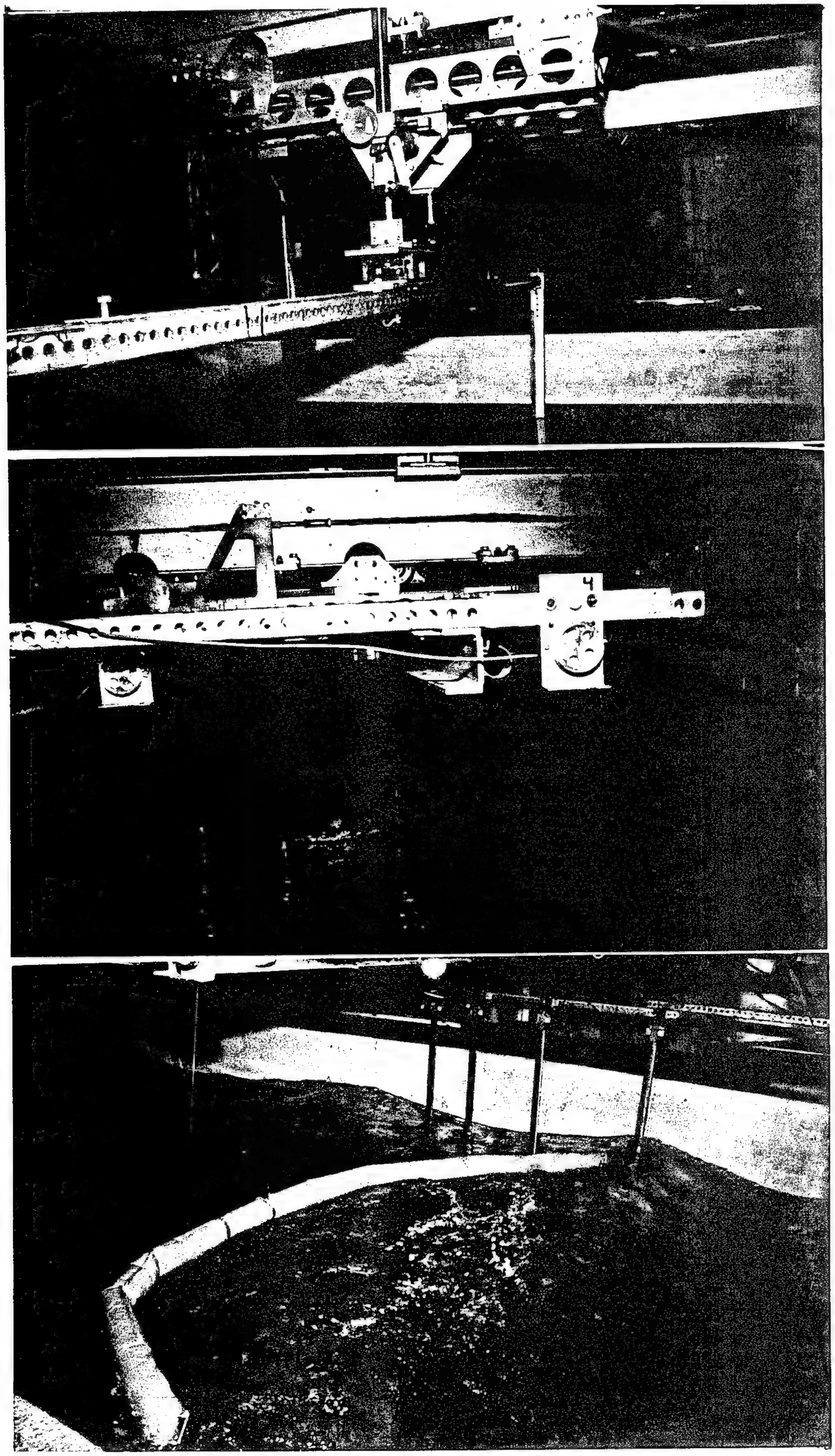


FIGURE 6 TOW RIG WITH DRAG BALANCE, HEAVE TRANSDUCER AND WAVE STRUTS SET FOR 12 FT BOOM LENGTH

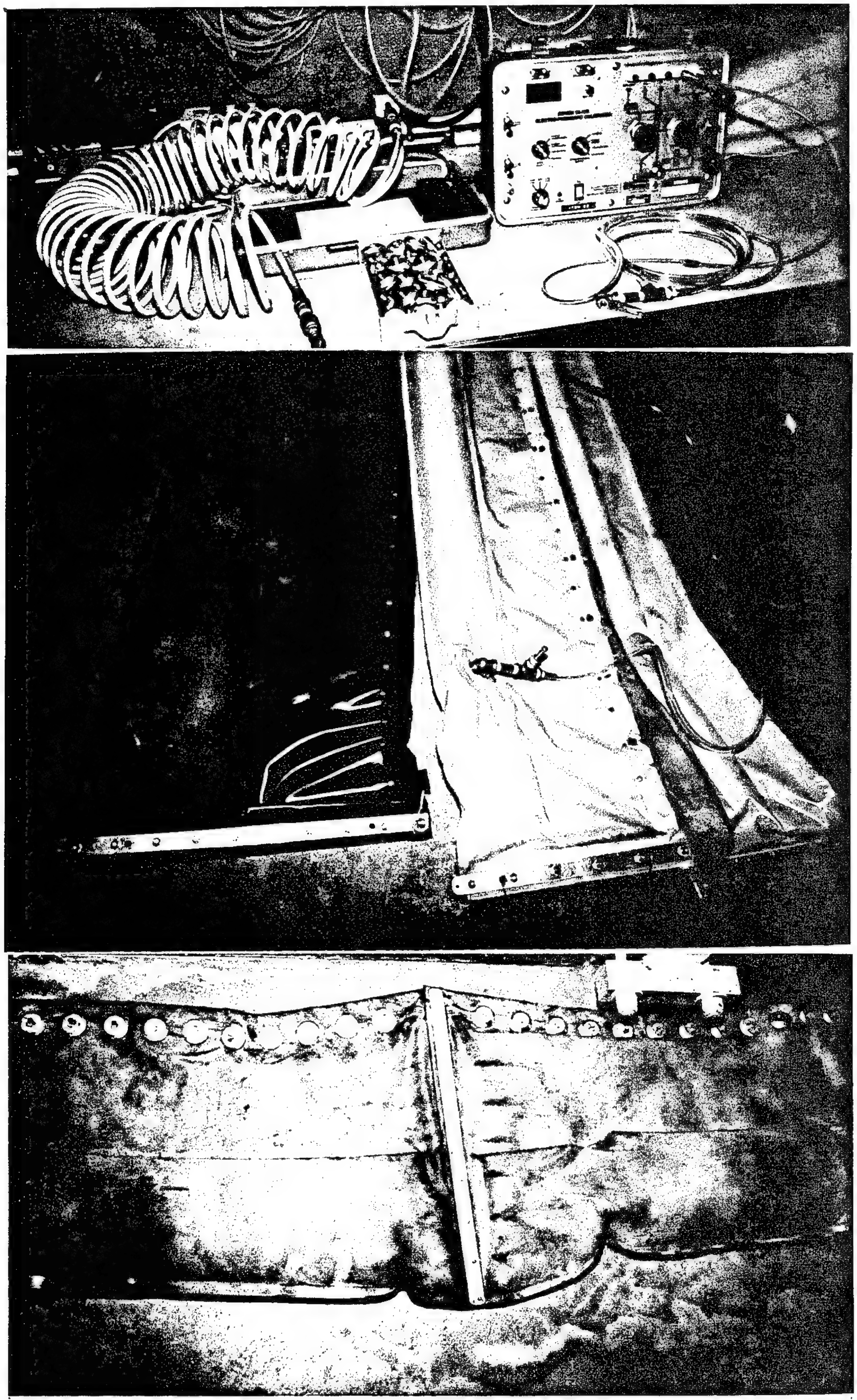


FIGURE 7 PRESSURE SYSTEM, BOOMS AND WEIGHTS

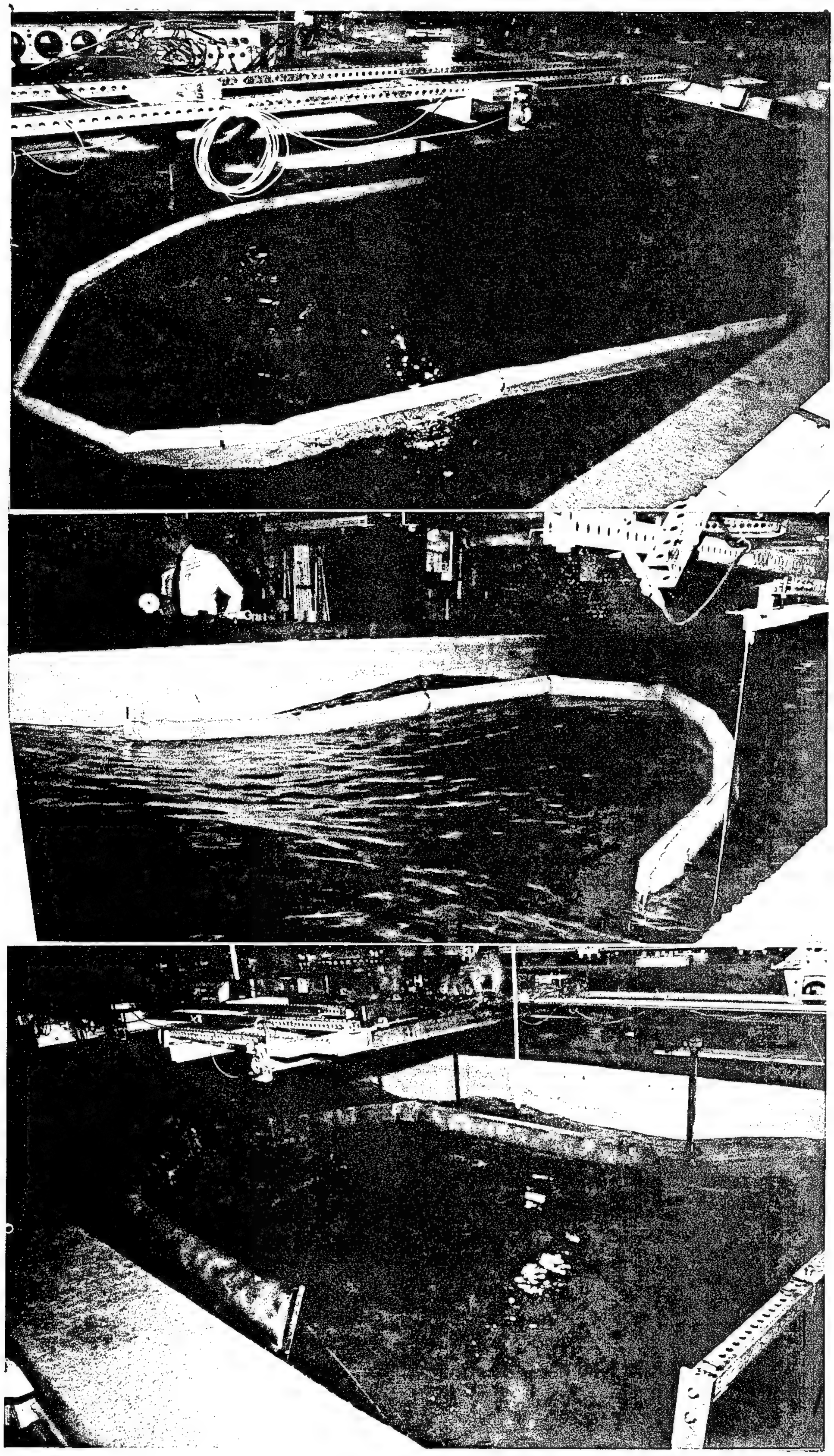


FIGURE 8 THREE SCALE BOOMS UNDER TEST

0.5 ft x 24 ft Boom at B/W = 16.2 at 0.303 fps - Run 61
0.75 ft Significant Height Irregular Waves

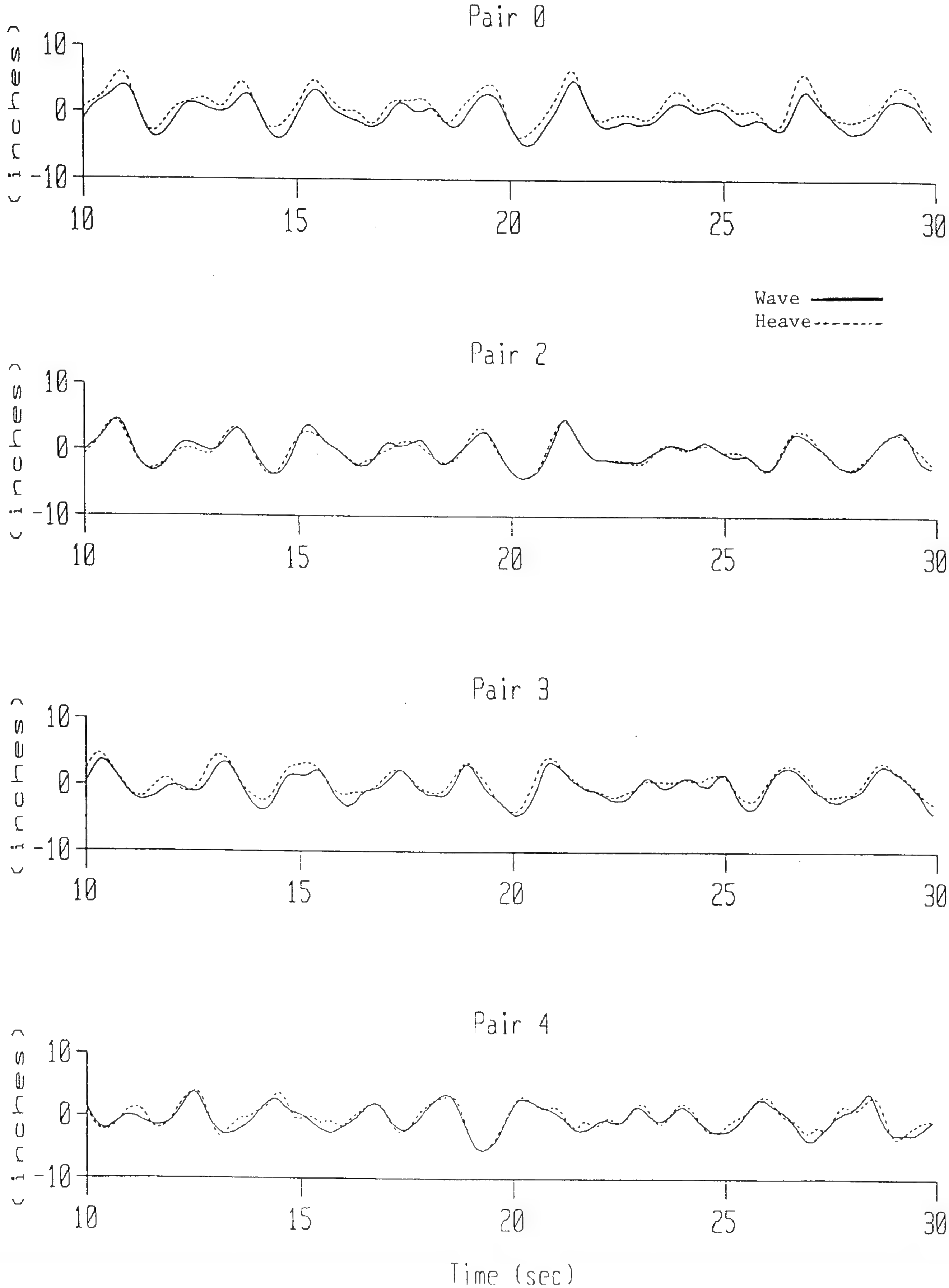


FIGURE 9 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

0.5 ft x 24 ft Boom at B/W = 12.5 at 0.303 fps - Run 90
0.75 ft Significant Height Irregular Waves

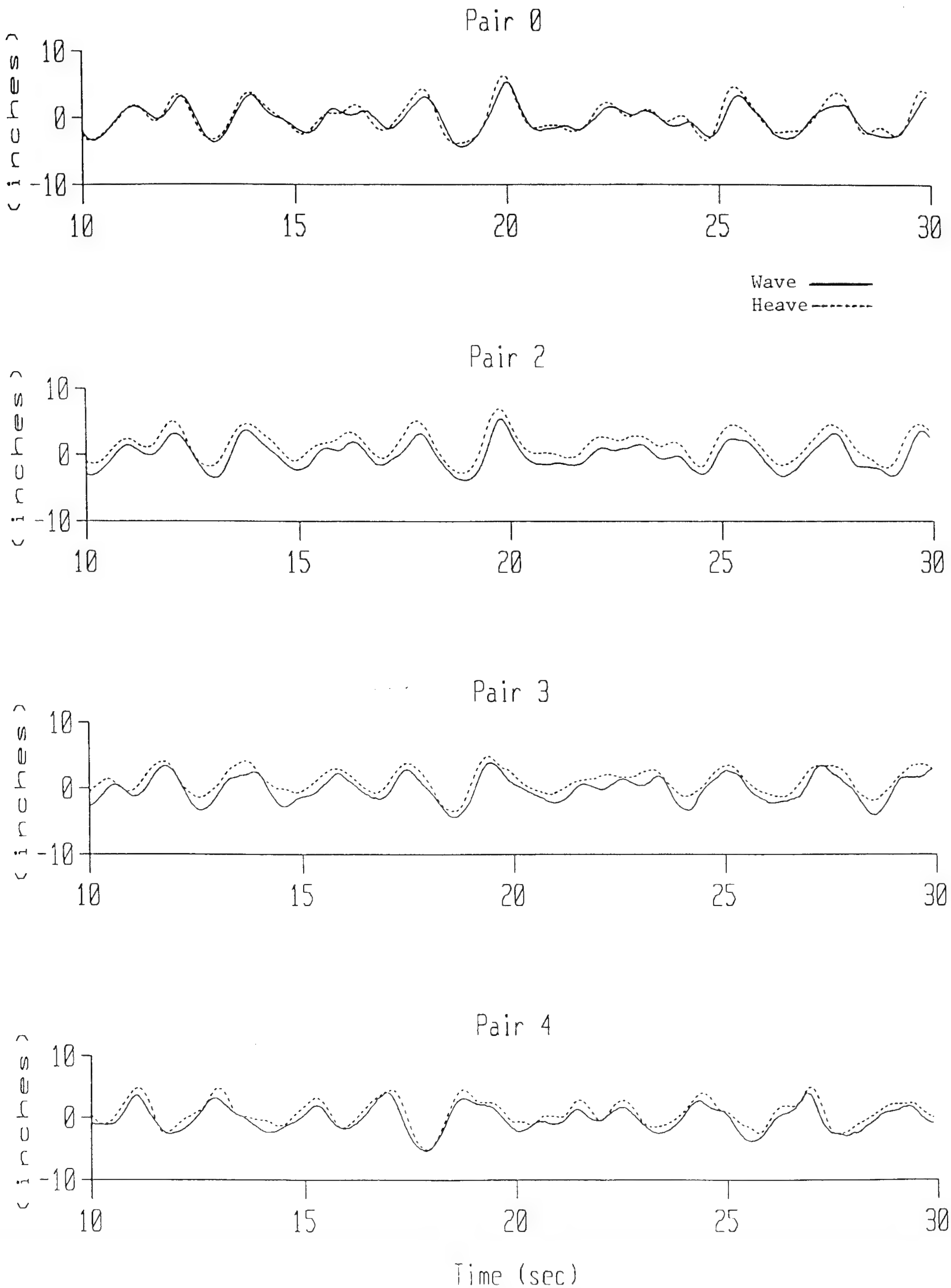


FIGURE 10 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

0.5 ft x 24 ft Boom at B/W = 9.6 at 0.304 fps - Run 75
0.75 ft Significant Height Irregular Waves

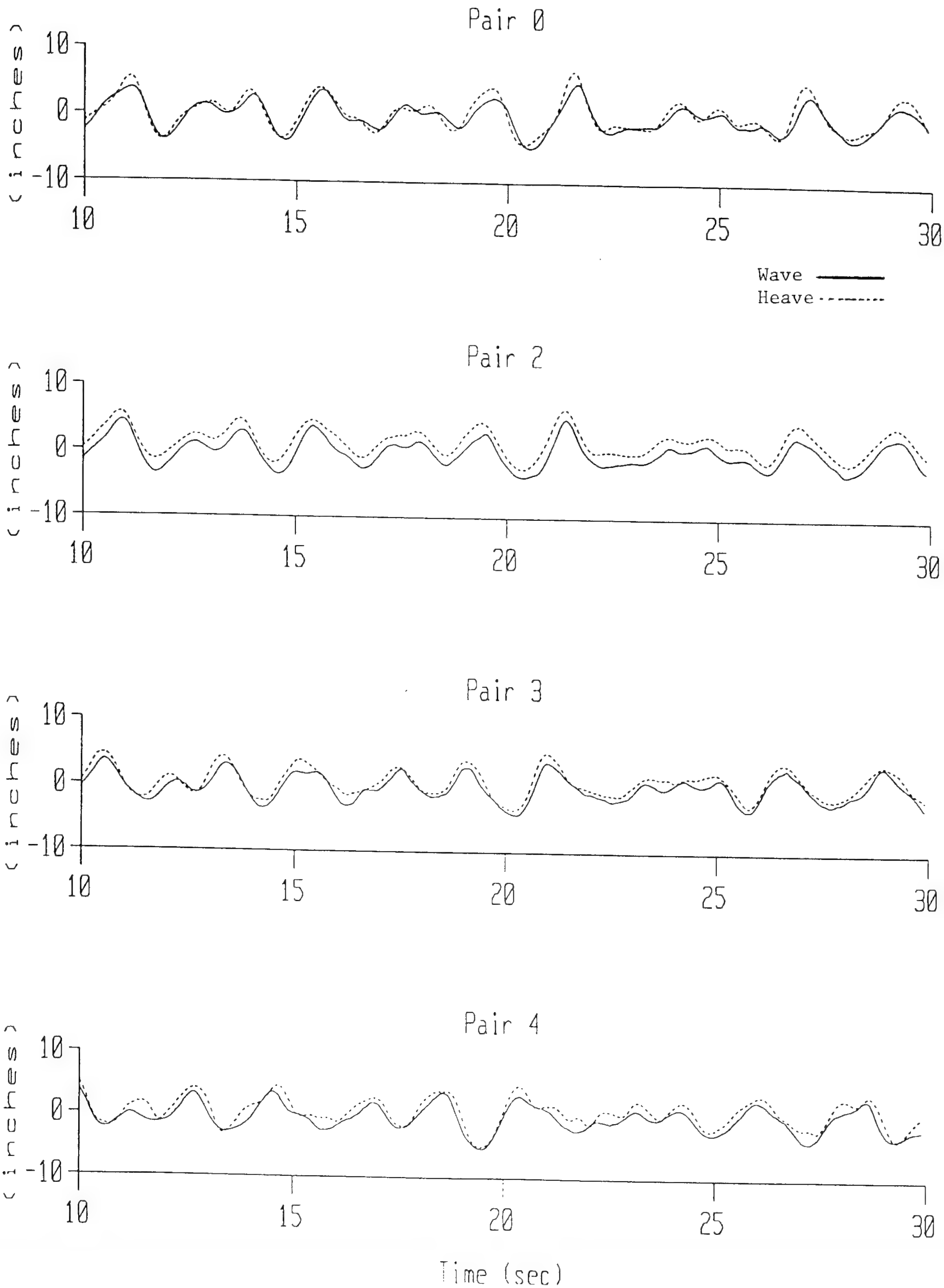


FIGURE 11 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.0 ft x 24 ft Boom at B/W = 34.3 at 0.397 fps - Run 13
0.75 ft Significant Height Irregular Waves

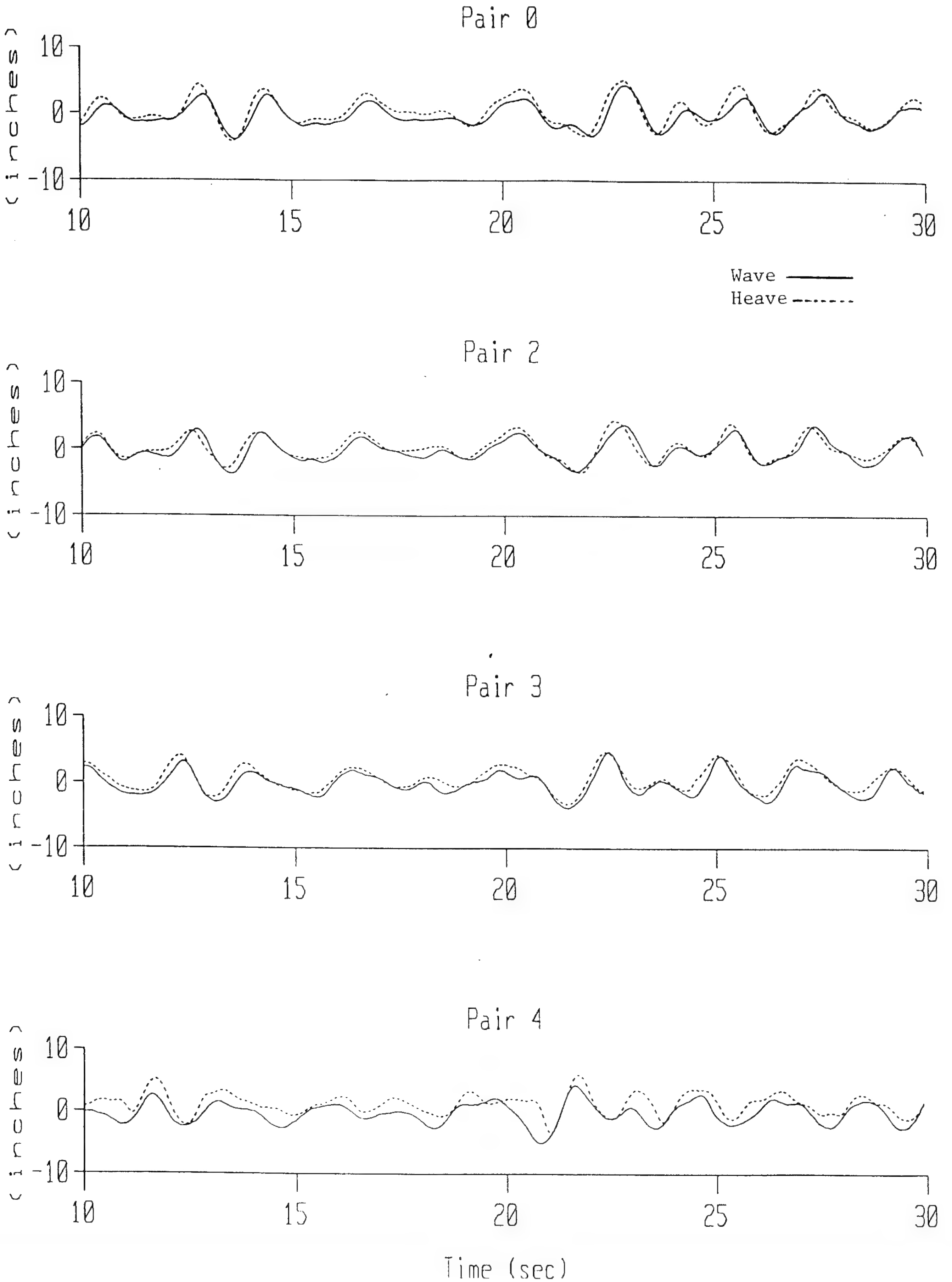


FIGURE 12 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.0 ft x 24 ft Boom at B/W = 10.4 at 0.396 fps - Run 29
0.75 ft Significant Height Irregular Waves

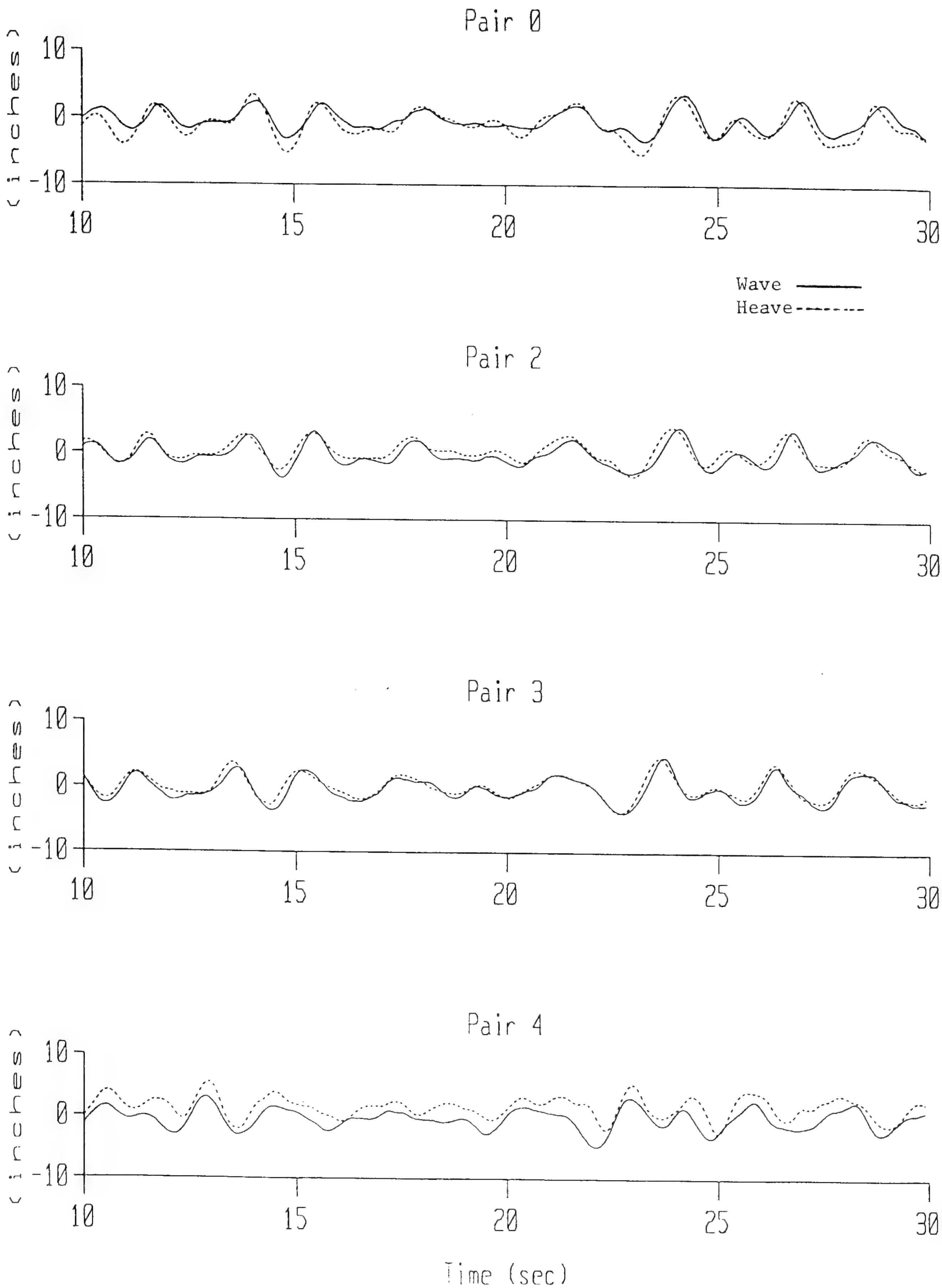


FIGURE 13 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMTNTS

1.0 ft x 24 ft Boom at B/W = 4.4 at 0.398 fps - Run 43
0.75 ft Significant Height Irregular Waves

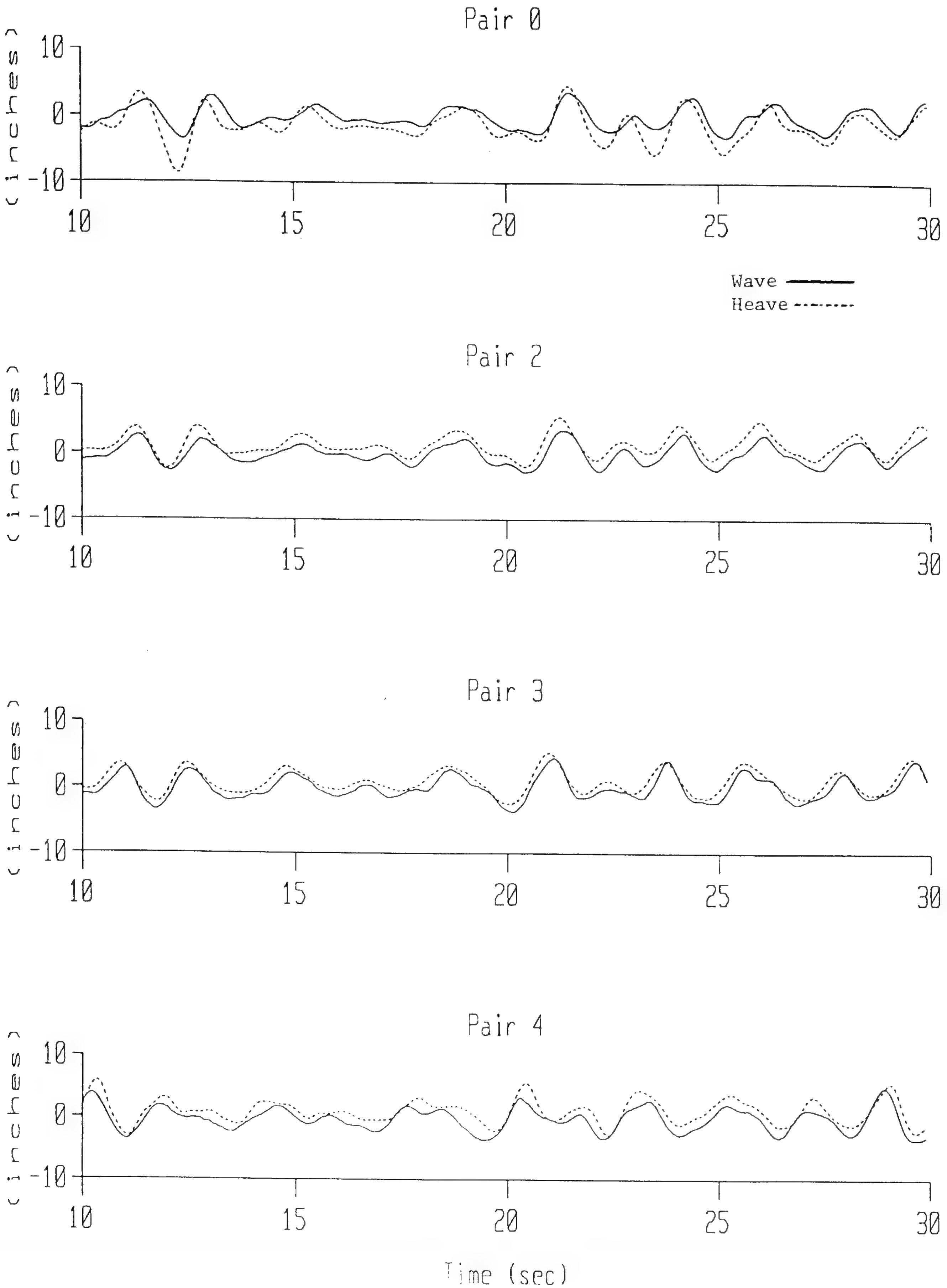


FIGURE 14 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.5 ft x 24 ft Boom at B/W = 33.6 at 0.490 fps - Run 110
0.75 ft Significant Height Irregular Waves

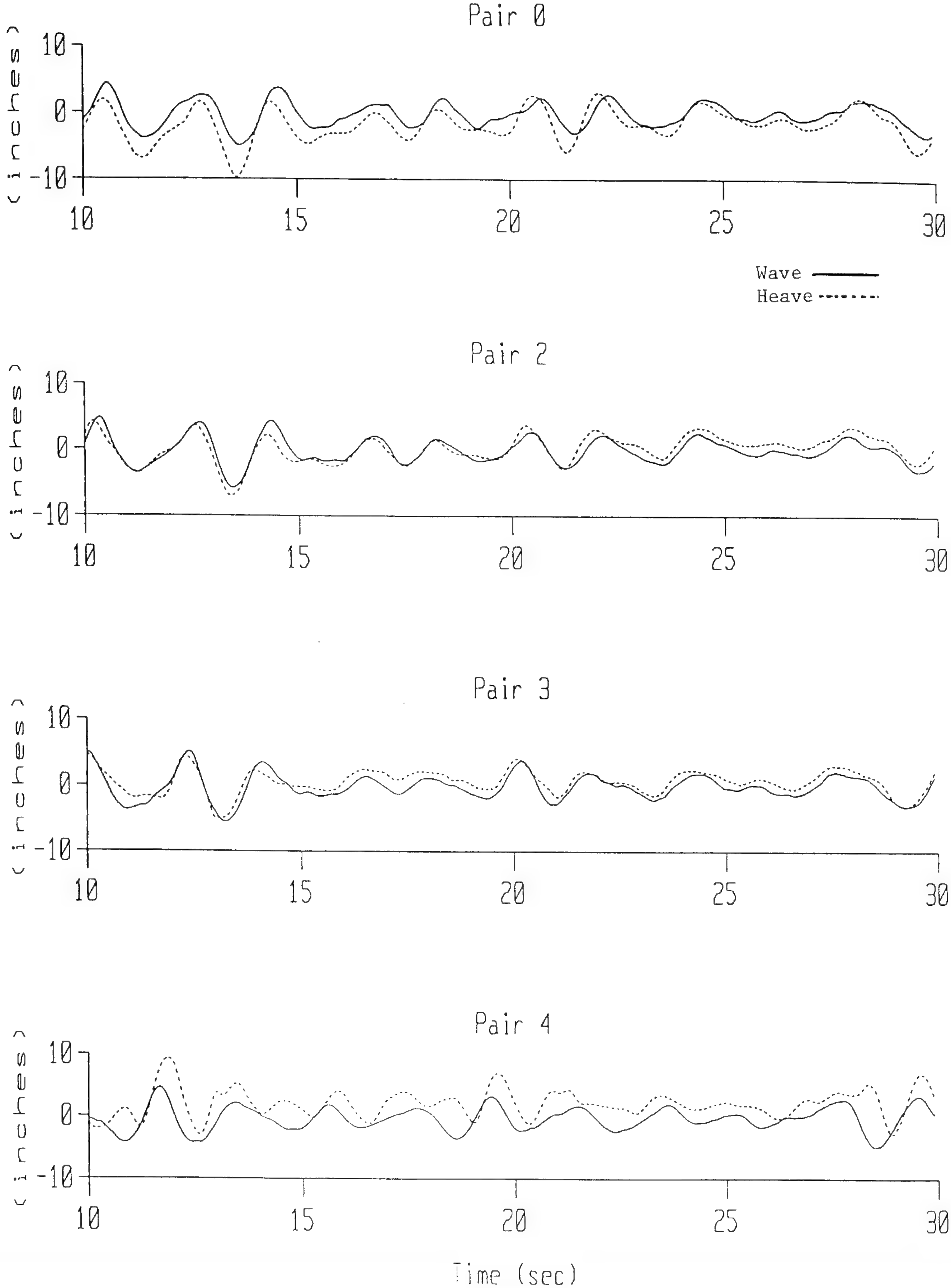


FIGURE 15 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.5 ft x 24 ft Boom at B/W = 10.3 at 0.503 fps - Run 126
0.75 ft Significant Height Irregular Waves

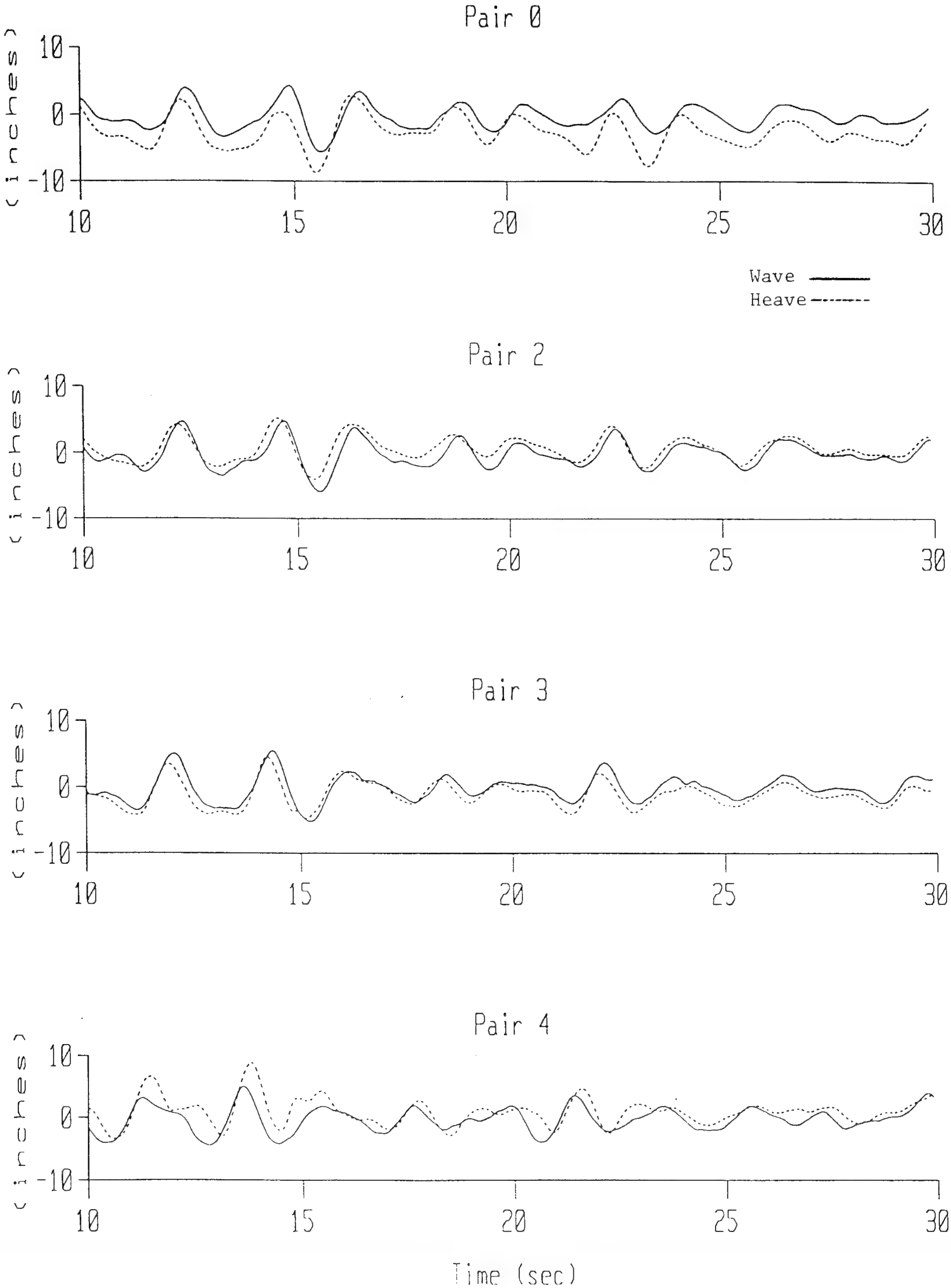


FIGURE 16 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.5 ft x 24 ft Boom at B/W = 5.0 at 0.501 fps - Run 142
0.75 ft Significant Height Irregular Waves

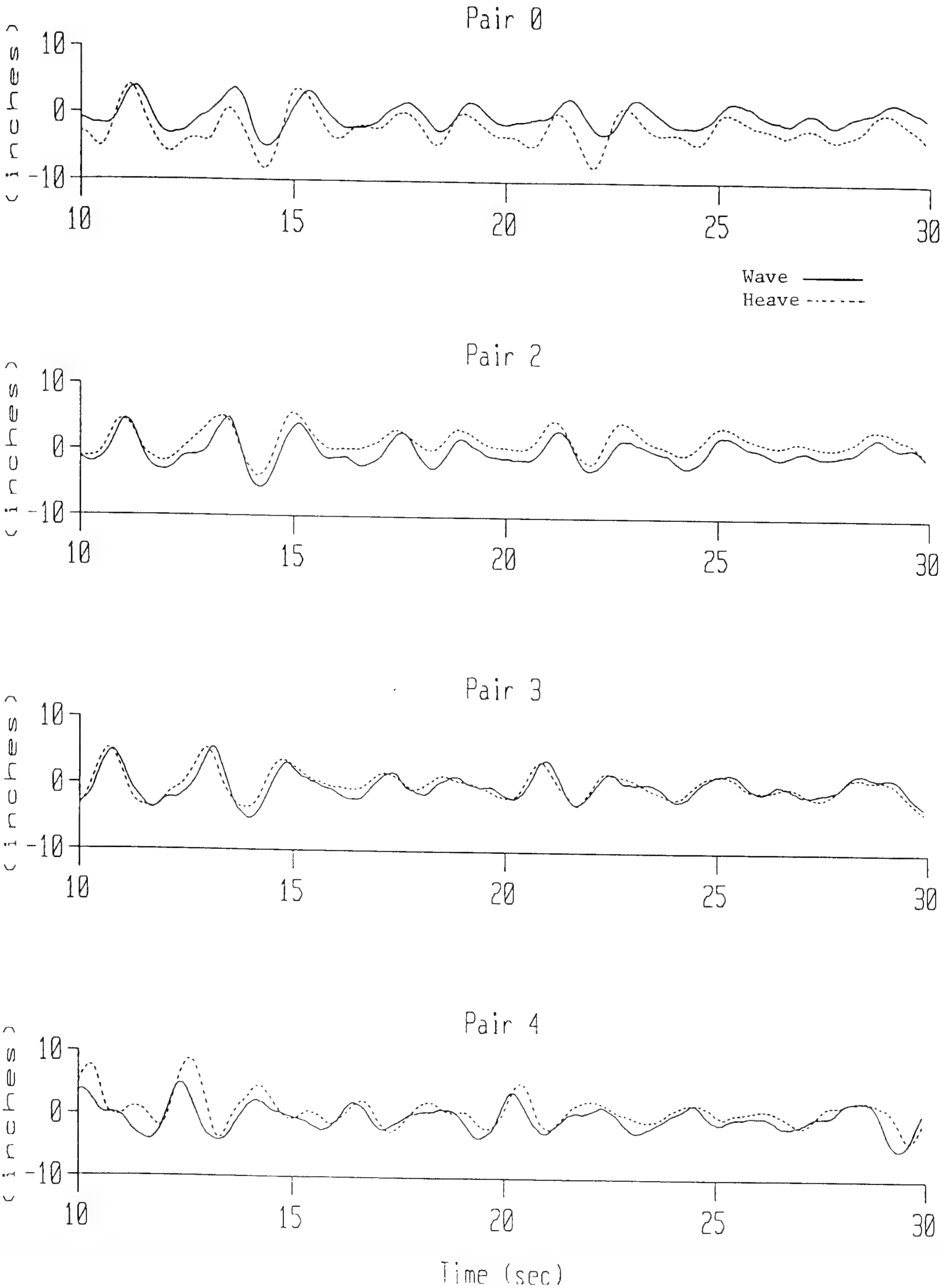


FIGURE 17 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

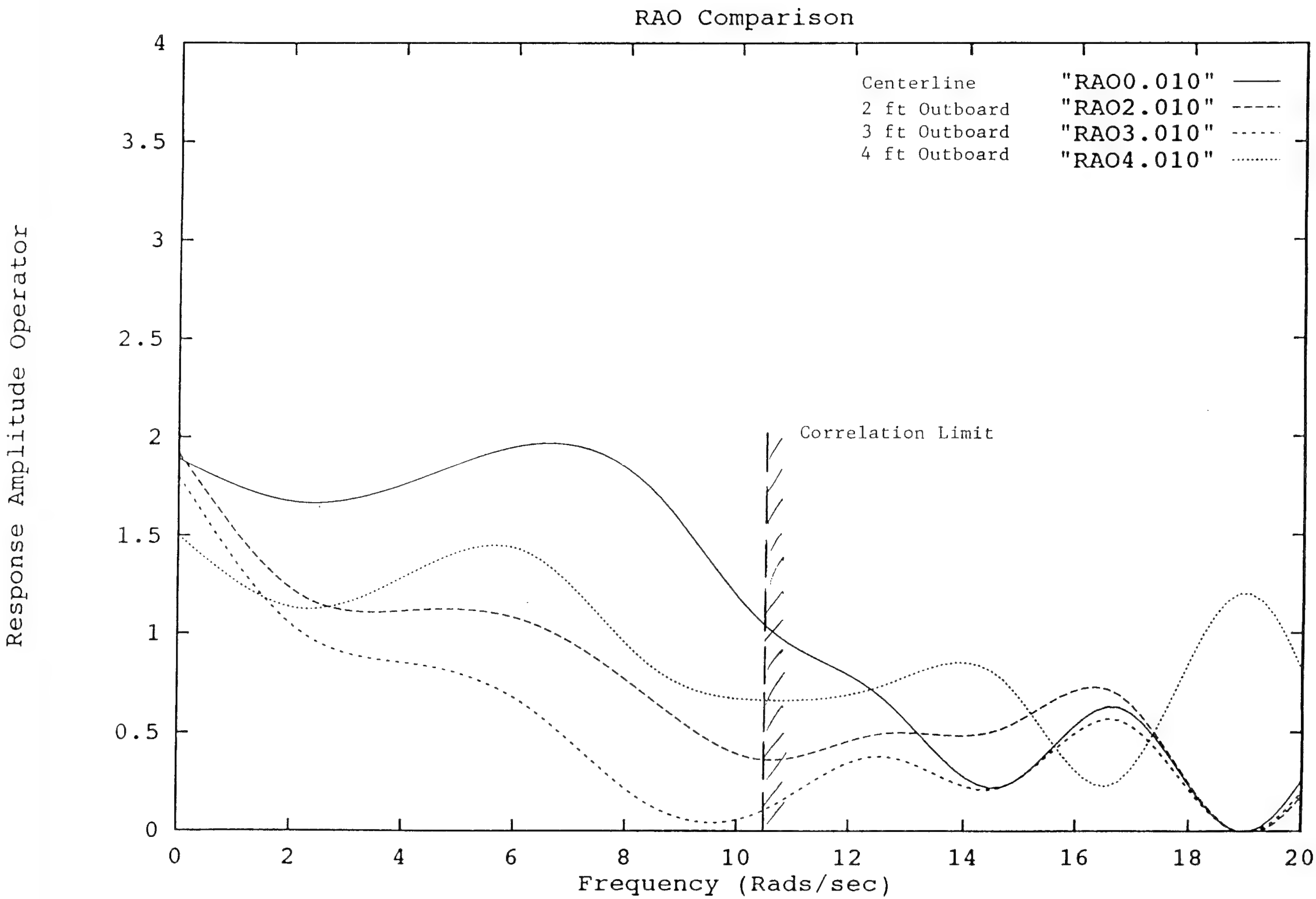


FIGURE 18 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT B/W = 34.3
1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.416 fps - Run 10

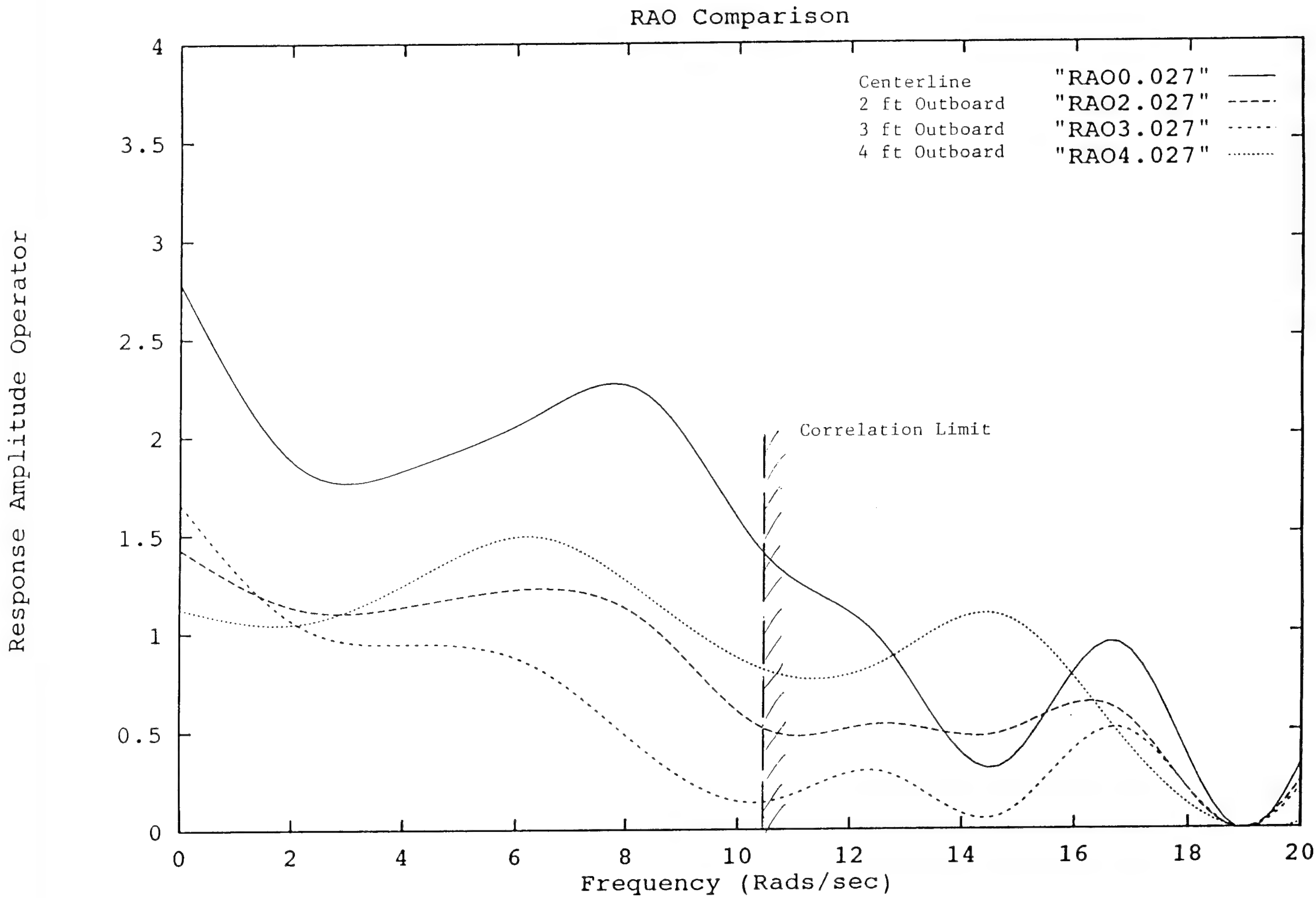


FIGURE 19 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT B/W = 10.4
1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.425 fps - Run 27

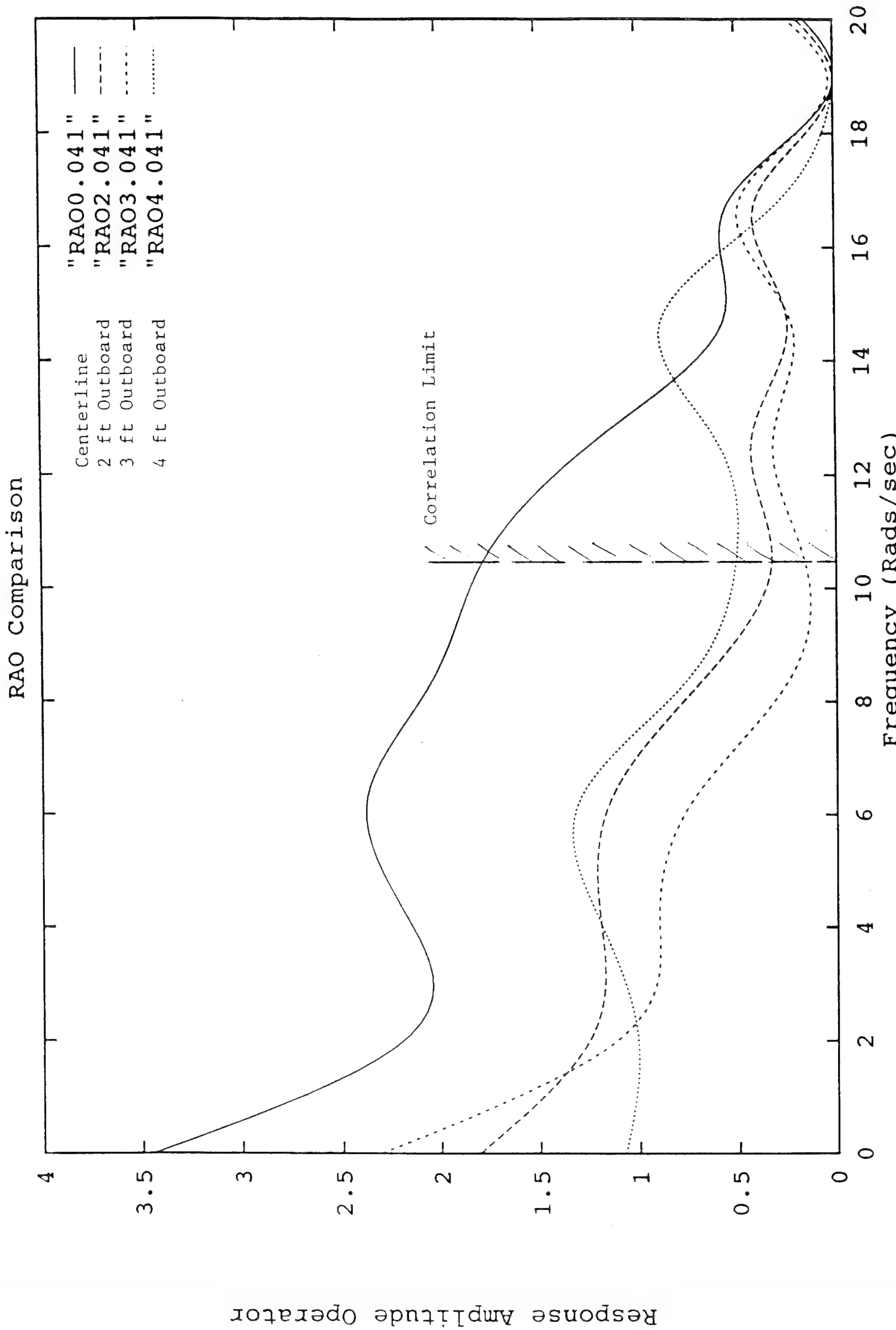


FIGURE 20 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT B/W = 4.4
1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.436 fps - Run 41

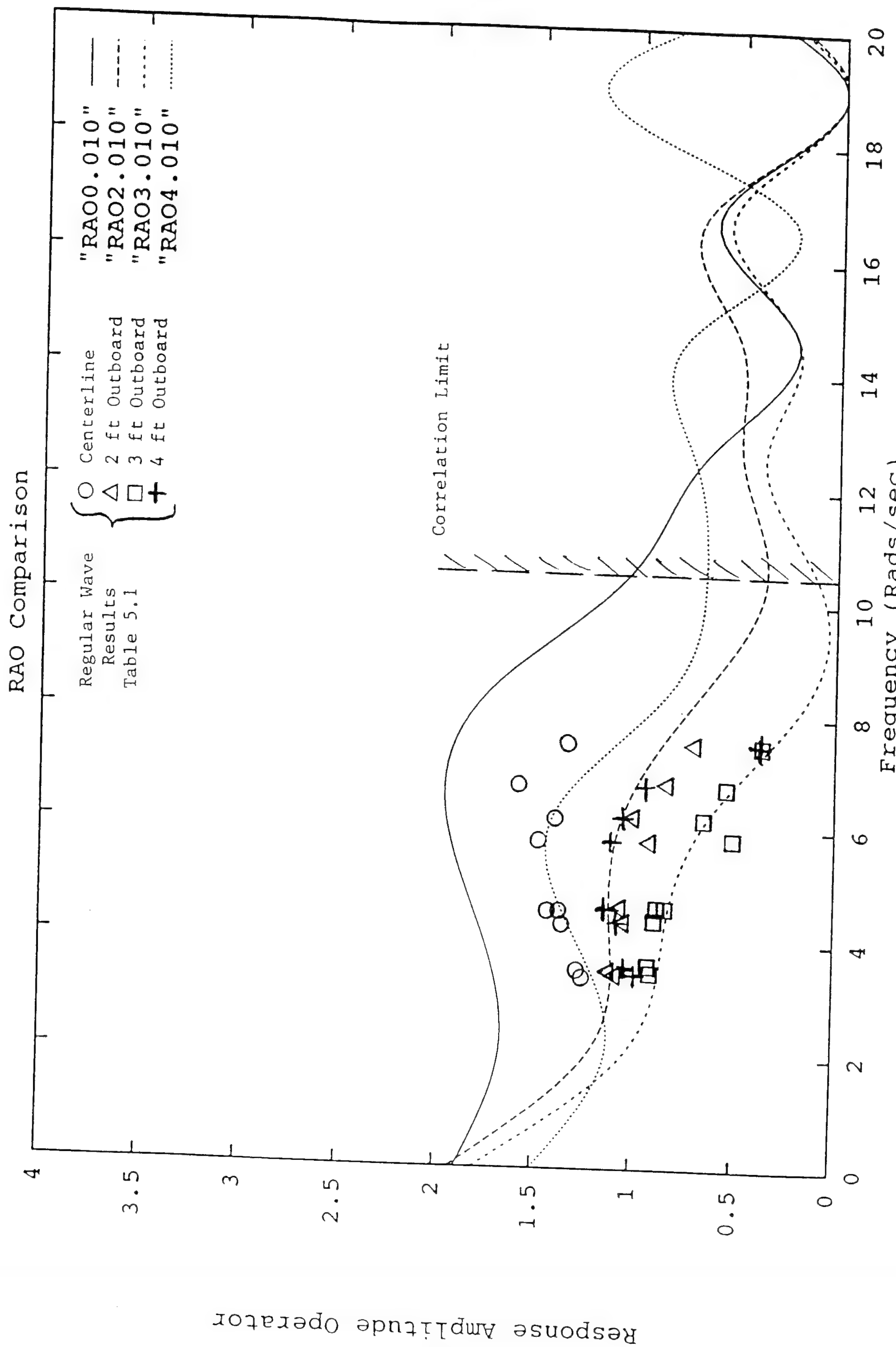


FIGURE 21 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT B/W = 34.3
1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.416 fps - Run 10

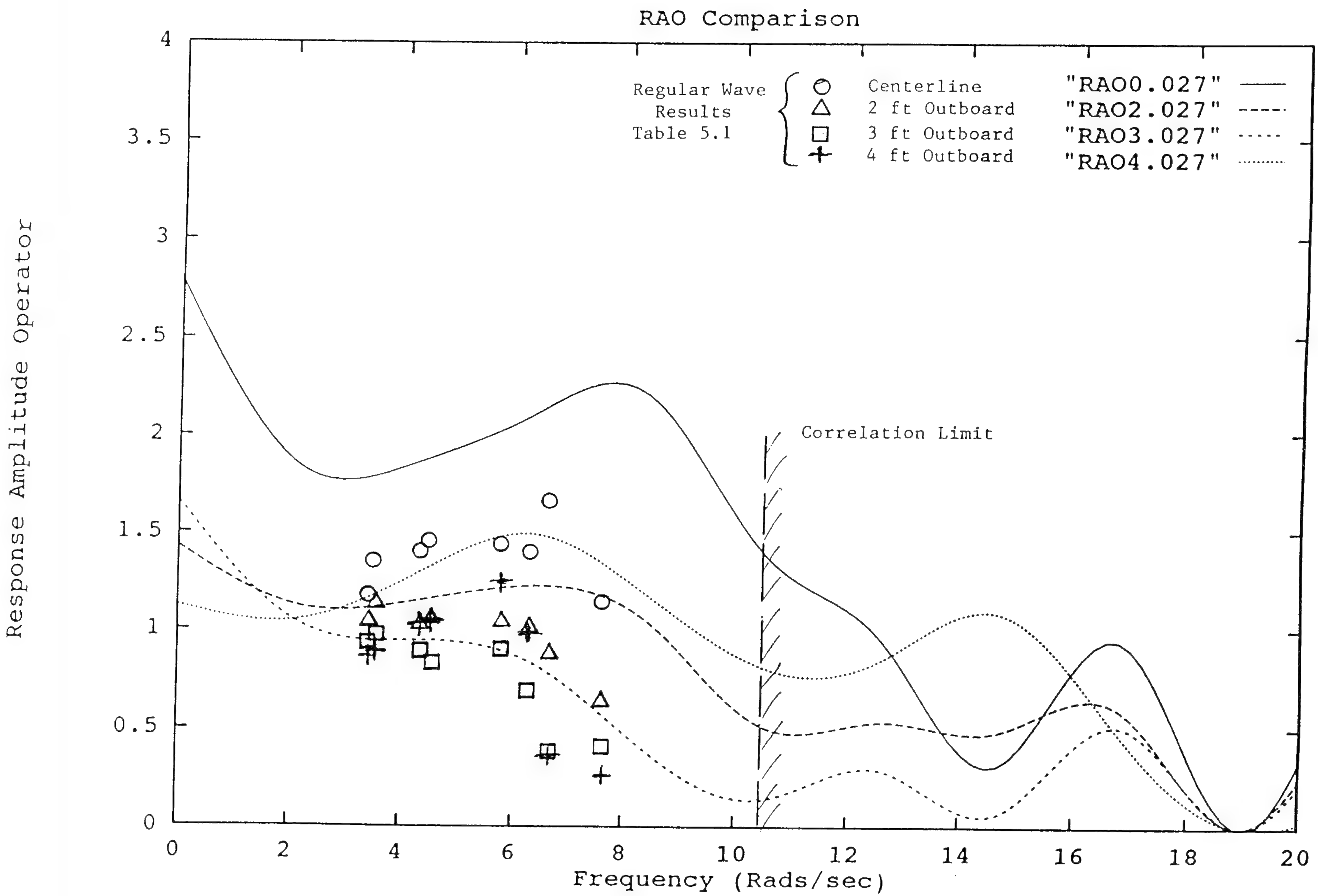


FIGURE 22 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT B/W = 10.4
1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.425 fps - Run 27

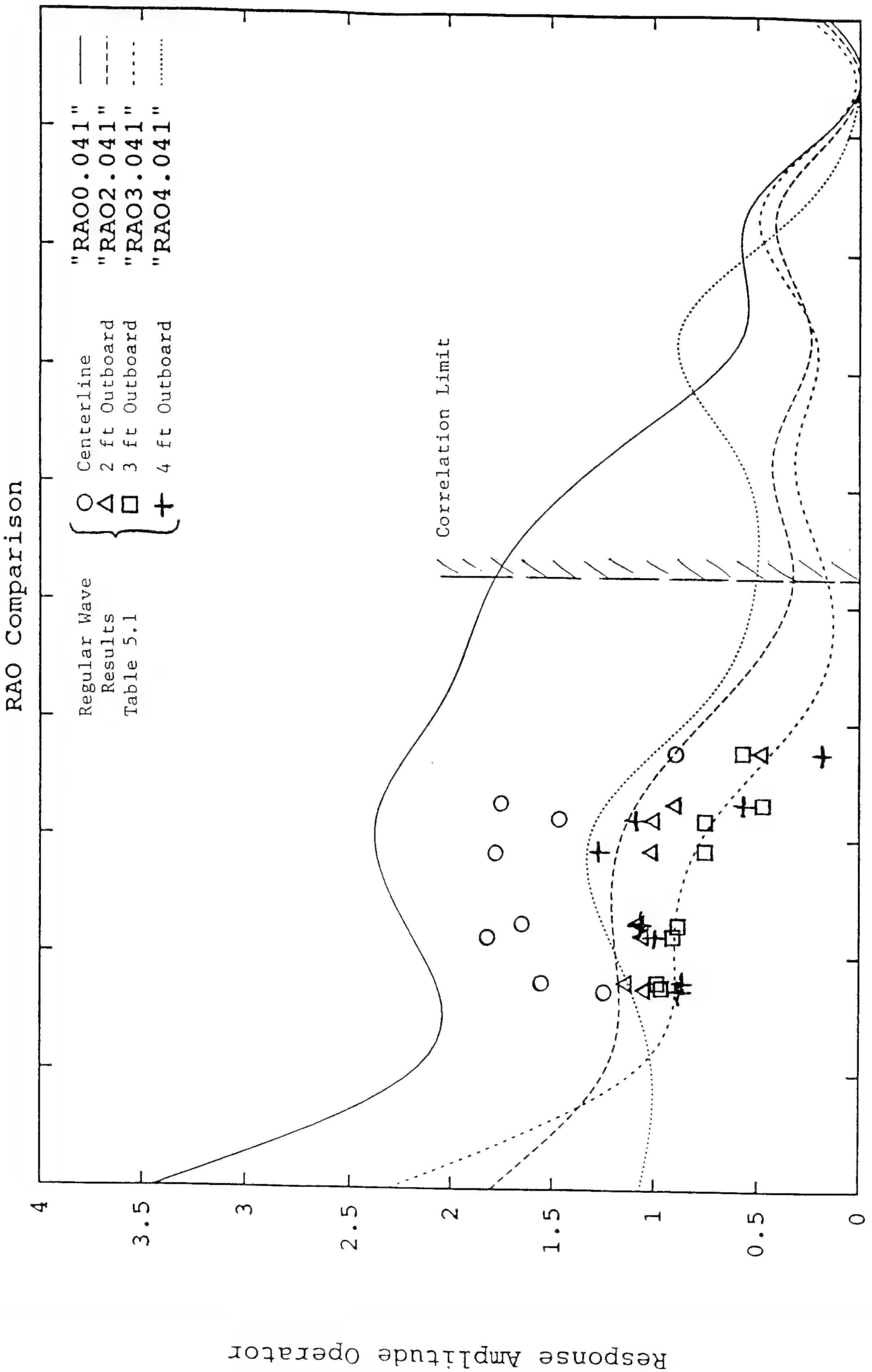


FIGURE 23 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT B/W = 4.4
1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.436 fps - Run 41

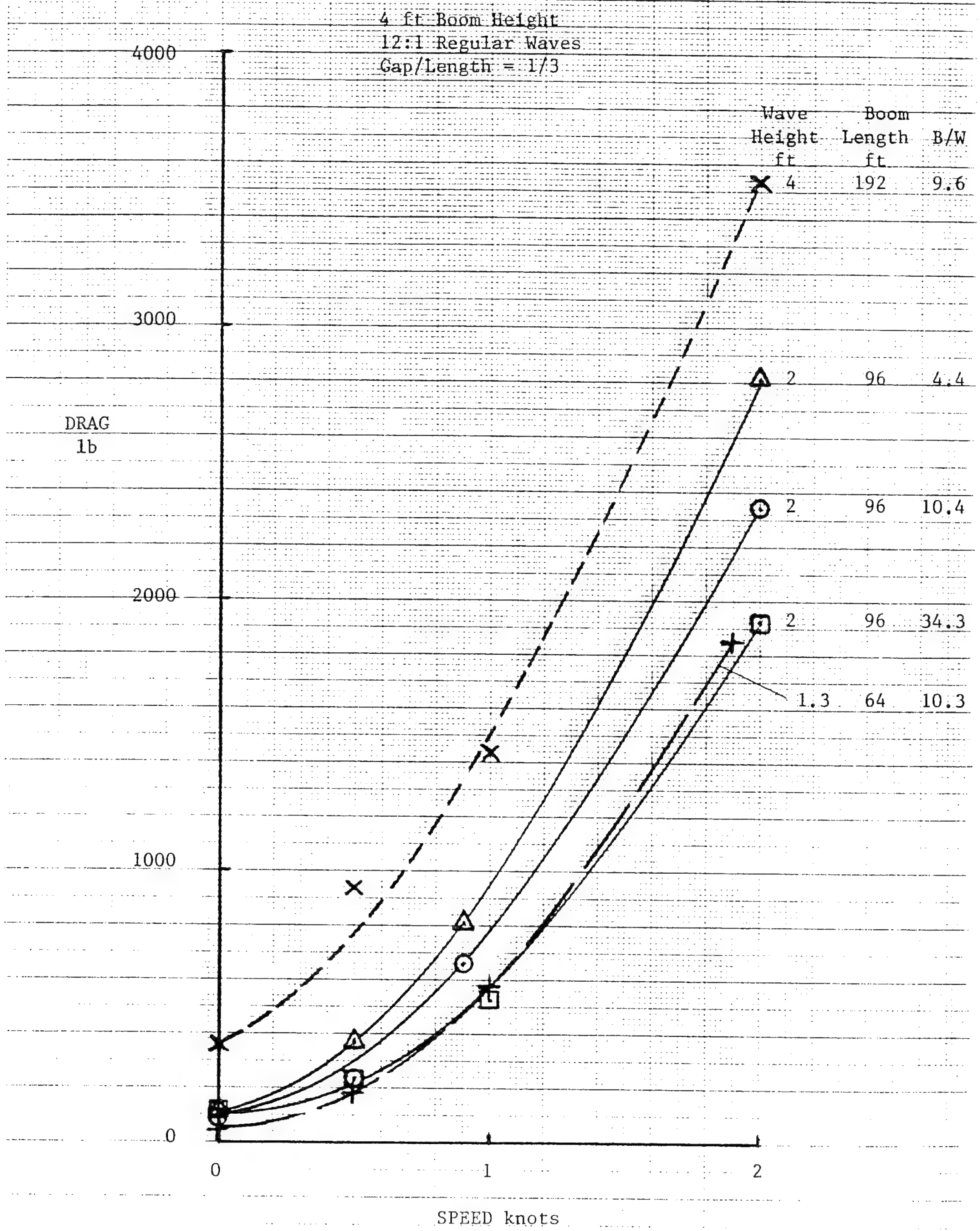


FIGURE 24 DRAG vs SPEED

Room Wave Calibrations

Scalar Spectrum Analysis   Page 1 of 1   Channel 1
Wave in

Run= 10,

645 Points   30 Lags   Delta-T= 0.200000 Sec
Scale constant= 1.000000E+00   Delta-Freq.= 0.083 Hertz

Sample Variance= 2.295474E+00 *90% Conf Intv.= 2.099385E+00 (Low)
Spectrum Area = 2.295474E+00 * = 2.522144E+00 (High)

43 Deg. Freedom: for 90% Conf. Bounds Multiply
Spectral Estimates by 0.73 and 1.48
Sig Wave Height = 6.0603 Inches

m0= 2.295   m1= 1.459
m2= 1.046   m3= 0.8705   m4= 0.8671
Modal period = 2.022 Sec (0.495 Hz)
Average period (m0/m1) = 1.573 Sec (0.636 Hz)
Z-cross period (sqrt(m0/m2)) = 1.481 Sec (0.675 Hz)
Band-width Parameter (sqrt(1-m2**2/(m0*m4))) = 0.671

Lag	Fre-quency	Spectral Estimates*	ITTC Spectrum +	
0	0.000	8.4037E-03	0.0000E+00	*
1	0.083	2.4749E-02	5.3743E-12	*
2	0.167	6.8869E-04	1.6795E-13	*
3	0.250	7.5647E-02	3.4111E-06	*
4	0.333	1.0181E+00	3.9110E-01	¦ + *
5	0.417	3.6693E+00	4.5818E+00	¦ * +
6	0.500	5.6559E+00	6.6537E+00	¦ *
7	0.583	5.6228E+00	5.3395E+00	¦ + *
8	0.667	4.1702E+00	3.5779E+00	¦ + *
9	0.750	2.6712E+00	2.2890E+00	¦ + *
10	0.833	1.6696E+00	1.4661E+00	¦ +*
11	0.917	8.4631E-01	9.5619E-01	¦ *+
12	1.000	6.1310E-01	6.3844E-01	¦ *
13	1.083	4.8123E-01	4.3673E-01	¦ +*
14	1.167	2.7757E-01	3.0573E-01	¦*+
15	1.250	1.5954E-01	2.1865E-01	¦*
16	1.333	1.6952E-01	1.5945E-01	¦*
17	1.417	1.5057E-01	1.1836E-01	¦*
18	1.500	8.3482E-02	8.9275E-02	*
19	1.583	3.3314E-02	6.8324E-02	*
20	1.667	2.8896E-02	5.2985E-02	*
21	1.750	2.3912E-02	4.1586E-02	*
22	1.833	2.4143E-02	3.3000E-02	*
23	1.917	1.4542E-02	2.6452E-02	*
24	2.000	1.4649E-02	2.1400E-02	*
25	2.083	8.7755E-03	1.7462E-02	*
26	2.167	1.1329E-02	1.4360E-02	*
27	2.250	7.1525E-03	1.1897E-02	*
28	2.333	8.5863E-03	9.9225E-03	*
29	2.417	3.8212E-03	8.3285E-03	*
30	2.500	6.0244E-03	7.0319E-03	*

APPENDIX A-1
IRREGULAR WAVE SPECTRUM
6 INCH SIGNIFICANT HEIGHT

Boom Wave Calibrations

Scalar Spectrum Analysis   Page 1 of 1   Channel 1
                                                            Wave in
Run= 9,

645 Points   30 Lags   Delta-T= 0.200000 Sec
Scale constant= 1.000000E+00   Delta-Freq.= 0.083 Hertz

Sample Variance= 5.038975E+00 *90% Conf Intv.= 4.608525E+00 (Low)
Spectrum Area = 5.038975E+00 * = 5.536557E+00 (High)

43 Deg. Freedom: for 90% Conf. Bounds Multiply
Spectral Estimates by 0.73 and 1.48
Sig Wave Height = 8.9791 Inches

m0= 5.039   m1= 2.616
m2= 1.543   m3= 1.061   m4= 0.8831
Modal period = 2.484 Sec (0.403 Hz)
Average period (m0/m1) = 1.926 Sec (0.519 Hz)
Z-cross period (sqrt(m0/m2)) = 1.807 Sec (0.553 Hz)
Band-width Parameter (sqrt(1-m2**2/(m0*m4))) = 0.682

Lag	Fre- quency	Spectral Estimates*	ITTC Spectrum +	------------------------------
0	0.000	1.7319E-01	0.0000E+00	*
1	0.083	9.0253E-02	5.1696E-12	*
2	0.167	1.3767E-01	1.6155E-13	*
3	0.250	1.8877E+00	1.5258E-01	+ *
4	0.333	8.9676E+00	1.1278E+01	¦ * +
5	0.417	1.5310E+01	1.7745E+01	¦ *
6	0.500	1.3130E+01	1.2529E+01	¦ +*
7	0.583	8.3969E+00	7.3808E+00	¦ + *
8	0.667	4.8514E+00	4.2566E+00	¦ + *
9	0.750	2.8558E+00	2.5142E+00	¦ +*
10	0.833	1.8020E+00	1.5385E+00	¦ +*
11	0.917	1.1053E+00	9.7613E-01	¦ *
12	1.000	6.4884E-01	6.4046E-01	¦*
13	1.083	4.3315E-01	4.3310E-01	¦*
14	1.167	2.6909E-01	3.0083E-01	¦*
15	1.250	1.4105E-01	2.1397E-01	*
16	1.333	8.3871E-02	1.5543E-01	*
17	1.417	6.5825E-02	1.1504E-01	*
18	1.500	5.1234E-02	8.6591E-02	*
19	1.583	4.4385E-02	6.6163E-02	*
20	1.667	2.9273E-02	5.1245E-02	*
21	1.750	2.0588E-02	4.0182E-02	*
22	1.833	1.4594E-02	3.1862E-02	*
23	1.917	1.0427E-02	2.5524E-02	*
24	2.000	6.0393E-03	2.0640E-02	*
25	2.083	6.5076E-03	1.6834E-02	*
26	2.167	5.0304E-03	1.3840E-02	*
27	2.250	6.9904E-03	1.1462E-02	*
28	2.333	4.5282E-03	9.5583E-03	*
29	2.417	4.1125E-03	8.0212E-03	*
30	2.500	2.4698E-03	6.7714E-03	*

APPENDIX A-2
IRREGULAR WAVE SPECTRUM
9 INCH SIGNIFICANT HEIGHT

Boom Conformance Tests

Scalar Spectrum Analysis Channel 8
Wave 4, in

Run= 60,

924 Points 30 Lags Delta-T= 0.250000 Sec
Scale constant= 1.000000E+00 Delta-Freq.= 0.067 Hertz

Sample Variance= 9.821496E+00 *90% Conf Intv.= 9.112664E+00 (Low)
Spectrum Area = 9.821497E+00 * = 1.062153E+01 (High)

61 Deg. Freedom: for 90% Conf. Bounds Multiply
Spectral Estimates by 0.76 and 1.39

Sig Wave Height = 12.5357 Inches

m0= 9.821 m1= 4.561
m2= 2.468 m3= 1.601 m4= 1.277

Modal period = 2.773 Sec (0.361 Hz)
Average period (m0/m1) = 2.154 Sec (0.464 Hz)
Z-cross period (sqrt(m0/m2)) = 1.995 Sec (0.501 Hz)
Band-width Parameter (sqrt(1-m2**2/(m0*m4))) = 0.717

Lag	Fre-quency	Spectral Estimates*	ITTC Spectrum +	
0	0.000	6.2897E-01	0.0000E+00	+*
1	0.067	5.9232E-01	1.9822E-11	+*
2	0.133	4.6584E-01	6.1945E-13	*
3	0.200	2.3772E+00	4.7533E-03	+ *
4	0.267	1.3417E+01	9.4316E+00	+ *
5	0.333	2.8128E+01	3.6466E+01	* >
6	0.400	3.3248E+01	3.5561E+01	*
7	0.467	2.6107E+01	2.4059E+01	+ *
8	0.533	1.3990E+01	1.4840E+01	*
9	0.600	7.6527E+00	9.0844E+00	*+
10	0.667	5.9505E+00	5.6737E+00	*
11	0.733	4.7877E+00	3.6445E+00	+*
12	0.800	3.1028E+00	2.4100E+00	+*
13	0.867	2.0875E+00	1.6382E+00	+*
14	0.933	1.8103E+00	1.1418E+00	+*
15	1.000	1.0590E+00	8.1416E-01	*
16	1.067	5.9690E-01	5.9245E-01	*
17	1.133	4.2700E-01	4.3907E-01	*
18	1.200	3.3571E-01	3.3079E-01	*
19	1.267	2.0751E-01	2.5294E-01	*
20	1.333	1.4146E-01	1.9602E-01	*
21	1.400	9.6933E-02	1.5377E-01	*
22	1.467	7.9066E-02	1.2197E-01	*
23	1.533	5.9088E-02	9.7734E-02	*
24	1.600	6.4571E-02	7.9047E-02	*
25	1.667	5.2767E-02	6.4484E-02	*
26	1.733	3.8608E-02	5.3023E-02	*
27	1.800	3.1662E-02	4.3919E-02	*
28	1.867	4.5112E-02	3.6627E-02	*
29	1.933	3.5424E-02	3.0740E-02	*
30	2.000	3.8797E-02	2.5952E-02	*

APPENDIX A-3
IRREGULAR WAVE SPECTRUM
12 INCH SIGNIFICANT HEIGHT

HEAVE

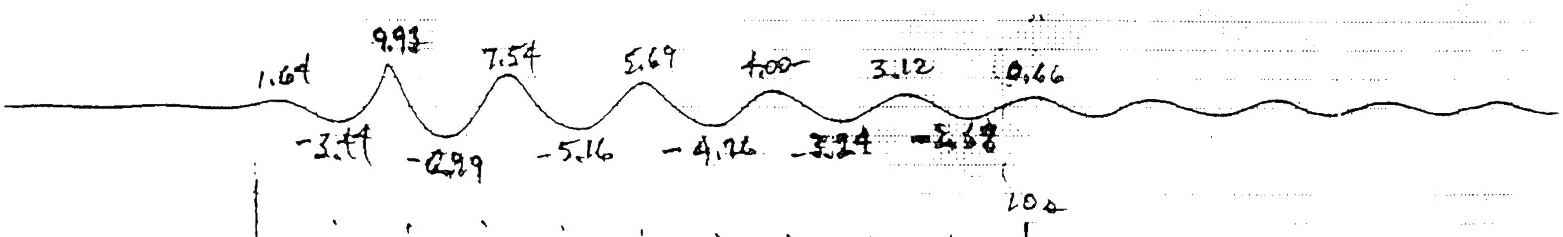
```
Run      :    15        7 Oscillations
Ch    1  : Wave in          Buffer :      0.500

      Peaks     Troughs

      1.636     -3.437
      9.932     -6.990
      7.536     -5.156
      5.685     -4.264
      3.999     -3.239
      3.123     -2.677
      0.661     -0.066

RUN   R P C CI K L H O O . ??      c 15
 Which channel ?       1
```

MT-3600 MULTI-TASK RECORDER



WAVE WIRE

CARR TACH

APPENDIX A-4
BREAKING WAVE TIME HISTORY SAMPLE